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JOURNAL OF PALEONTOLOGY

A Publication of the Society of Economic Paleontologists and Mineralogists,
a Division of
The American Association of Petroleum Geologists

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JOURNAL of PALEONTOLOGY

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ERRATA

In "Micropaleontology of the Pennsylvanian Johns Valley Shale of the Ouachita Mountains, Oklahoma, and its Relationship to the Mississippian Caney Shale," by Bruce H. Harlton, Journal of Paleontology, March, 1933, page 18, Explanation of Plate 6, 9*a–d*, *Amphissites bushi* Harlton n. sp. ×26 should be 10*a–d*, and 10*a*, *b Aechminella trispinosa* Harlton n. sp. ×33 should be 9*a*, *b*.

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A STUDY OF THE ECHINOID FRAGMENTS IN THE CRETACEOUS ROCKS OF TEXAS

JEROME S. SMISER
Princeton University

ABSTRACT

Attention is first called to the abundant occurrence of echinoid fragments in the Cretaceous rocks of Texas and their possible usefulness as guide fossils. The more important previous works on Texas echinoids are discussed. The stratigraphic distribution of echinoids in the Texas Cretaceous is given in a chart, followed by a description of the more important echinoid zones and horizons. The technique of studying fragments is discussed. A key to the genera of Texas Cretaceous echinoids based on fragments is included and is followed by a systematic description of the fragments of most of the genera and many species of Texas Cretaceous echinoids. A bibliography is included.

INTRODUCTION

Paleontologists have been studying echinoids for many years, but they have confined their investigations almost wholly to complete specimens. The recent increase in the study of microfossils has called attention to the abundance of fragments from macrofossils in many formations. The occurrence of such fragments in samples containing few other identifiable fossils has suggested the desirability of studying them to determine the species to which they belong. The writer has undertaken to do this with a number of Cretaceous echinoids from Texas. It is hoped that his investigation will increase our knowledge of the faunas in the Cretaceous of Texas, and will demonstrate the desirability of studying fragments of macrofossils as well as entire specimens.

No attempt has been made to describe all the fragments of echinoids found in the Texas Cretaceous, but fragments of most of the genera and many of the species are dealt with in this study. The descriptions of the fragments from some of the species have been based entirely on examination of complete specimens, or from descriptions and figures in the literature. Although fragments of these particular forms have not been seen by the writer, they undoubtedly occur and can be recognized when present. The distribution of echinoids in the Texas Cretaceous is given, the stratigraphic significance of certain of the early Cretaceous species is explained, and the technique used in studying the fragments is described. Descriptions are given for the fragments of numerous common genera and species, and some rarer forms which are of stratigraphic significance.

This work is a border-line study between micropaleontology and macropaleontology. Paleontologists have used the microscope in studying complete macrofossils and microfossils, and some have even described new forms from fragments. Few, if any, special studies of the fragments alone have been made. It is believed that this type of study will not only lead to the use of fragments, but will also result in a fuller knowledge of the details of the complete fossils. The primary object has been to determine the value of these fragments to the paleontologist, and the secondary object has been to develop the best methods of studying the fragments and identifying them.

The first part of this investigation was carried out at Texas Christian University. The work was finished at Princeton University[1] partly with the aid of a Storrow Fellowship from the National Research Council.

ACKNOWLEDGMENTS

The writer is indebted to Professors W. M. Winton, Gayle Scott and C. I. Alexander of the Department of Geology of Texas Christian University for their continual interest, assistance, and encouragement during the progress of this research. Professors John R. Sandidge and B. F. Howell have advised the writer during his studies at Princeton University.

[1] This paper is an extract from a Doctor's dissertation. In order to conserve space a chapter reviewing the stratigraphy of the Cretaceous of North-Central Texas and one on general features of the echinoid test have been excluded. An unabridged edition of the dissertation can be secured by loan from the Princeton University Library, or this information can be secured from numerous publications listed in the bibliography for that purpose.

PREVIOUS WORK ON THE CRETACEOUS ECHINOIDS OF TEXAS

The Cretaceous echinoids of Texas have been studied and described by nearly all the invertebrate paleontologists who have had occasion to work on the Cretaceous faunas of that state. The earliest writers to deal with Cretaceous echinoids from Texas were, F. Roemer, B. F. Shumard, F. F. Shumard, T. A. Conrad, James Hall and Jules Marcou. At a later date C. A. White, R. T. Hill, J. A. Taff and F. W. Cragin worked on Texas Cretaceous invertebrate faunas, and many descriptions of echinoids occur in their publications. Since the beginning of the twentieth century the most comprehensive publication that was based partly on echinoids from the Texas Cretaceous has been that of W. B. Clark and M. W. Twitchell on the Mesozoic and Cenozoic Echinodermata of the United States (1915). M. Jules Lambert of Paris, France, has recently published (1927) on Texas Cretaceous echinoids. W. S. Adkins, of the Bureau of Economic Geology of Texas, published in 1928 a handbook of Texas Cretaceous fossils, in which are included those echinoids which had been described up to that time.

Most of the literature containing descriptions or figures of Texas Cretaceous echinoids is listed in the bibliography. A few of the more important works should, however, probably be mentioned at this time. F. Roemer's "Texas" (1849) and "Die Kreidebildungen von Texas" (1852) contain the first descriptions of echinoids from the Cretaceous of the state. B. F. Shumard's report on fossils collected by the Marcy Expedition up the Red River (1854); T. A. Conrad's and James Hall's reports in the Mexican Boundary Survey of Emory (1857); Marcou's Geology of North America (1858); Shumard's report on fossils collected by the Pope Expedition along the Pecos (1886), also deserve special mention. R. T. Hill's "Black and Grand Prairies of Texas" is important for its contribution to our knowledge of the geology and paleontology of Texas.

It was published in 1901. Emil Böse's "Geológica y Paleontológica del Cerro de Muleros" contains descriptions and figures of numerous echinoids common to the Cretaceous of Texas and Mexico. Lambert and Thiéry's "Essai de nomenclature raisonnée des échinides" (1909–25) is most important in connection with the classification of the echinoids. In 1926, Professor Gayle Scott requested M. Jules Lambert to make a study of some echinoids from the Texas Cretaceous and compare them with similar French Cretaceous echinoids. The results of this study were published by Professor Scott in his "Études stratigraphique et paléontologiques sur les terrains crétacés du Texas," under the heading "Notes critiques sur quelques échinides du crétacé du Texas." Later M. Lambert published "considérations sur les échinides de la commanche série du Texas" in the Bulletin de la Société Geologique de France. This study was based upon echinoids furnished to M. Lambert by Professor Scott. The latest summary of Texas Cretaceous echinoids is given in W. S. Adkins' "Handbook of Texas Cretaceous Fossils," referred to above.

The above-mentioned studies have been based on complete, or nearly complete, fossil echinoids. A few echinoids have been described from fragments; but no work of the type attempted in the present study has been done. None have attempted to identify fragments as parts of particular genera and species except in a few instances where certain fragments were unmistakable. This border-line study therefore opens up a new field of study, of particular interest to the micropaleontologist, and will bring groups of macrofossils to the aid of the subsurface investigator.

DISTRIBUTION OF ECHINOIDS IN THE CRETACEOUS OF TEXAS

The lowest Texas Cretaceous formation from which echinoids have been described is the Glen Rose formation of the Trinity group. From this formation upward there are only one or two formations which have not contributed complete, or at least recognizable, specimens of this class of echinoderms. These fossils are most abundant in the Fredericksburg and Washita groups, especially the latter. In the upper portion of the Washita group, echinoids become extremely abundant. The greatest number of different species probably occurs in the Fort Worth formation; but the Goodland formation of the Fredericksburg group, and all the Washita formations, are marked by a very great abundance of certain species. The Goodland formation contains nearly all of the echinoids found within the Fredericksburg group.

Below the Fredericksburg group and above the Washita group echinoids form a much smaller part of the total invertebrate fauna. In the Trinity group, below the Fredericksburg, the only important echinoids are *Loriolia texana* (Clark), *Hemiaster comanchei* Clark, and *Heteraster obliquatus* (Clark), all of which occur in the Glen Rose formation.

In the Upper Cretaceous, immediately above the Washita group, echinoids occur in very limited numbers, and are nearly all concentrated in two formations, the Austin chalk and Taylor marl. Even there they are relatively unimportant.

Naturally the distribution of the fragments found corresponds closely to the distribution of the complete fossils. In some cases the fragments occur in formations which to the writer's knowledge have yielded no complete specimens. In the matter of abundance, the distribution of the complete fossils and that of the fragments is identical.

Species of Echinoids	Trinity			Fred'sburg					Washita										Upper Cretaceous					
	Travis Peak	Glen Rose	Paluxy	Walnut	Goodland	Comanche Peak	Edwards	Kiamichi	Duck Creek	Fort Worth	Denton	Weno	Pawpaw	Main Street	Grayson	Georgetown	Del Rio	Buda	Woodbine	Eagle Ford	Austin	Anacacho	Taylor	Navarro
Dorocidaris texanus (Clark)										Washita (Bexar county)														
Cidaris dixiensis Cragin																							x	
Leiocidaris hemigranosus (Shumard)											x				?									
Loriolia texana (Clark)	x	x		x?																				
Loriolia ornata (Clark)														x	(Washita at Fort Worth).									
Echinopsis lineatus (Clark)															x									
Tetragramma taffi (Cragin)						x																		
Tetragramma streeruwitzi (Cragin)										Washita				x										
Tetragramma (?) hilli (Clark)																					x			
Polydiadema texanum (Roemer)					x	x																x		
Leptarbacia arguta Clark										Washita							x							
Orthopsis occidentalis Cragin										Washita (Sierra Blanca)														
Orthopsis panulata Clark															x									
Micropedina symmetrica (Cragin)									x			x												
Salenia prestensis ? Agassiz					x																			
Salenia texana Credner					x	?				Washita (Bexar county)														
Salenia mexicana Schluter					x																			
Salenia volana Whitney																		x						
Goniophorus scotti Lambert									x															
Peltastes sp. Adkins															x									
Phymosoma texanum (Roemer)					x	x																		
Phymosoma mexicanum Böse										x	x													
Phymosoma volanum (Cragin)										Denison beds								x						
Cottaldia rotula Clark																		x						
Codiopsis texanus Whitney																		x						
Codiopsis sp. aff. valotairei Lambert																					x			
Goniopygus zitteli Clark							x																	
Goniopygus budaensis Whitney																		x						
Holectypus engerrandi Lambert		x																						
Holectypus planatus Roemer					x	x			x?	x				x	x?									
Holectypus planus Giebel					x?																			
Holectypus transpecosensis Cragin						Comanchean (Sierra Blanca)																		
Holectypus limitis Böse										x	x			x	?									
Holectypus charltoni Cragin														x	x									
Holectypus castilloi Cotteau																x								
Pyrina inaudita Böse										x	x													
Pseudopyrina clarki (Böse)										x	x													
Pseudopyrina parryi (Hall)										Lower Washita (Leon Springs)														
Pseudopyrina (?) bulloides (Cragin)					x																			
Porobrissus angustatus (Clark)																		x						
Procassidulus sp. (Adkins)																			Escondido.					
Holaster simplex Shumard									x	x		x												
Holaster comanchesi Marcou									x?															
Holaster nanus Cragin															x?									
Holaster nodulosus Goldfuss											x													
Pseudananchys completus (Cragin)														x	Denison beds									
Pseudananchys supernus (Cragin)														x										
Echinocorys texanus (Cragin)																						x		
Echinocorys cf. texanus (Cragin)																							x	
Heteraster texanus (Roemer)				Fredericksburg								Washita												
Heteraster obliquatus (Clark)		x																						
Heteraster bohmi De Loriol						Comanchean (Fort Worth)																		
Heteraster texasus (d Orbigny)					x																			
Heteraster bravoensis (Böse)										x	x	x	x											
Heteraster wenoensis (Adkins)												x	x											
Heteraster traski (Whitney)																		x						
Heteraster adkinsi Lambert									x															
Heteraster inflatus (Cragin)															x									
Washitaster longisulcus (Adkins and Winton)										x														
Washitaster riovistae (Adkins)												x												
Macraster elegans (Shumard)									x	x														
Macraster texanus Roemer										x														
Macraster washitae Lambert										x?														
Macraster nodopyga Lambert										x														
Macraster aguilerae (Bose)										x	x													
Macraster subobesus (Adkins)												x												
Macraster wenoensis (Adkins)												x	x											
Macraster sp. Lambert					x	x																		
Epiaster bösei Lambert						x																		
Epiaster whitei (Clark)					x				x															
Hemiaster calvini Clark														x	x			x						
Hemiaster bexari Clark										Washita (Bexar county)														
Hemiaster comanchei Clark		x																						
Hemiaster texanus Roemer																					x			
Hemiaster americanus Giebel																					x			
Proraster dalli (Clark)										Washita (Bexar county)														

From the Trinity group fragments of *Loriolia texana* were found in the Glen Rose, but they were as rare as the complete fossils. In the Travis Peak formation fragments of this same form were found, although no complete *Loriolias* were described from this formation.

The fragments found in the Fredericksburg group of north Texas are concentrated in the middle Fredericksburg, or Goodland, formation, and to the south in the two equivalent formations, the Edwards and Comanche Peak. Fragments of certain commoner forms, such as the *Epiasters*, are relatively abundant in the Goodland, but that formation's yield of fragments does not approach that of the later Washita formations.

The Washita group is distinguished throughout its vertical extent by echinoids and their fragments. Nearly every concentrate prepared from Washita material contains echinoid fragments; and at certain levels in the Washita, spines and plates of echinoids comprise over half the organic content of a concentrate from that zone. The Fort Worth and Main Street formations contain more echinoid material than do the other Washita formations. Fragments of *Macraster* are particularly characteristic of the Fort Worth, while the genus *Holectypus* furnishes the bulk of the fragments occurring in the Main Street formation. The Grayson, Weno, and Duck Creek are nearly as prolific as the above-mentioned formations; but their washed concentrates are not quite so striking in content from our point of view.

The echinoid fragments of the Upper Cretaceous are unimportant. They do occur occasionally, but not in sufficient numbers to be significant.

Sufficient material could not be examined so that fragments of all the echinoids from the Texas Cretaceous might be secured; but fragments of the commoner forms, which are the most useful for correlation purposes have been studied and identified. Samples have been examined from all the Texas Cretaceous formations and from many localities in the state.

ECHINOID ZONES AND HORIZONS

Because of their value as index fossils complete fossil echinoids have been much used by stratigraphers in determining zones and horizons. Most of the zoning of the Fredericksburg and Washita groups of north Texas, which has been based wholly or in part on echinoids, has been done by Adkins and Winton.[2] The beds of these zones obviously contain a great number of fragments which can be definitely assigned to the species of echinoids which are characteristic of them. The zones and horizons marked wholly or in part by echinoids, as determined by Adkins and Winton, are listed below, beginning with the lower Fredericksburg, and extending upward through the Washita division. The fragments are usually as useful in identifying the zones as are the whole fossils, because they are abundant at these "horizons," belong to common species, and can be identi-

[2] Adkins, W. S., and Winton, W. M., Paleontological correlation of the Fredericksburg and Washita formations in north Texas: *Texas Univ. Bull.* 1945, 1919.

fied. Toward the limits of zones, where specimens of complete fossils are decreasing, fragments are also usually rare.

The lowest fossil zone in the Fredericksburg that is marked by an echinoid is the zone of the small, but easily identified, *Salenia mexicana* Schlüter. In the Fredericksburg of Tarrant County, this small echinoid is found about 85 feet above the top of the *Gryphea marcoui* Hill and Vaughan conglomerate, which is about 20 feet thick, occurring near the lower boundary of the Fredericksburg. This places the zone in question within the Goodland formation. The zone of *Salenia mexicana* Schlüter extends upward for only 3 feet and is immediately followed by another echinoid "horizon."

This latter "horizon" is marked by a greater abundance of *Macraster sp.* Lambert (a very small form previously referred to as *Hemiaster* sp. B) and *Heteraster texanus* (Roemer). It is 25 feet thick in the vicinity of Fort Worth. This "horizon" is probably 125 feet above the lowest Fredericksburg, and within the Goodland formation. The two echinoids marking it begin near the bottom of the Goodland, and the *Heteraster* ranges into the Washita; but their abundance and association at this level makes the horizon a distinctive one. *Holectypus planatus* Roemer also sometimes occurs at this "horizon" within the Goodland formation.

The "horizon" of *Holaster simplex* Clark "low phase," is of great vertical extent, but the abundance of specimens of this species, and the ease of their identification, always make its determination possible. This "low phase" is found at the top of the Duck Creek formation, and extends into the lower Fort Worth. It is abundant in the marls of the topmost Duck Creek and the limestones of the lowest Fort Worth. The "horizon" is marked by an abundance of its elongate, spatulate, ridged spines. The lower and upper limits of the "horizon" cannot be defined very closely. This particular form, called the "low phase," has its greatest perimeter at the base. Another form referred to as the "tall phase," which occurs higher in the Fort Worth formation, has the greatest perimeter above the base. In complete form these "phases" are easily differentiated, but their fragments cannot be told apart. The "tall phase," however, is very rare, fragments of it are so seldom found, and its zone is so restricted that it is not likely to be confused with the zone of the "low phase" even when the zones are determined by the fragments.

The middle of the Fort Worth formation is marked by an abundance of a very large echinoid, *Macraster elegans* (Shumard). This species has been confused by many workers with such species as *M. texanus*, *M. aguilerae* and *M. wenoensis*. It is not nearly so abundant as is commonly thought, and its reputation for abundance has been due to its similarity to the other forms mentioned above. It ranges from the upper Duck Creek throughout the entire Fort Worth formation. Its association with other fossils increases its value as a horizon

marker. *Macraster elegans* (Shumard) fragments have not been found very useful as index fossils of this zone because they can not be distinguished with certainty from fragments of certain similar species. When preserved as whole specimens they can be distinguished only by careful study and a thorough knowledge of all their details. The zone of *Macraster elegans* (Shumard) extends about 25 feet beyond the associated fossils above and below.

Immediately above this "horizon" or zone, there is a doubtful zone, less than two feet thick, that is marked by the "tall phase" of *Holaster simplex* Shumard. The difficulty of using echinoid fragments to determine this zone has been referred to above.

The top of the Fort Worth formation is marked by a zone less than five feet thick through which *Washitaster longisulcus* (Adkins and Winton) occurs. This species is easy to recognize and no similar forms occur very close to it above or below. In the fragments, the distinctive arrangement of the pores in the unpaired ambulacrum of this form easily separates it from the otherwise similar *Heteraster texanus* (Roemer). No difficulty whatever is encountered in identifying complete individuals of these two species. The fragments of *Washitaster longisulcus* (Adkins and Winton) are common in the top of the Fort Worth, and the zone can be located with the fragments as well as it can be with the complete fossils.

Leiocidaris hemigranosus Shumard, one of the largest and probably the most striking of Texas Cretaceous echinoids, is very rarely found complete. Spines which undoubtedly belong to it occur rather abundantly in the lower Denton formation. Other smaller spines are associated with these but also persist into later formations. This zone would be difficult to identify from the study of washed concentrates alone.

Although not given by Adkins and Winton as a zone indicator, *Washitaster riovistae* (Adkins) has been found to mark the Weno formation. It can be recognized by fragments, and is not easily confused with similar forms because none exist in this zone with unpaired ambulacra of the *Washitaster* type.

Holectypus limitis Böse occurs most abundantly at the base of the Main Street, but its spines and plates are very common through the whole of that formation. The Main Street has great numbers of remains of this one species, and comparatively few of other species, thus differing from such formations as the Fort Worth, in which fragments of several species are abundant.

The Upper Main Street and the Grayson contain *Hemiaster calvini* Clark, which can be identified from plates. The species is apparently more common in the Grayson than in the Main Street, as its fragments are more readily found in concentrates from that formation.

In the Upper Cretaceous series echinoids are not important enough nor common enough to require discussion here.

The importance of echinoids in Texas Cretaceous stratigraphy hav-

ing been explained, we will next proceed to a detailed discussion of the technique, and a study of the fragments of some representative forms.

TECHNIQUE

Identification of fossils is to a large extent a matter of comparison and this rule applies to fragments as well as to whole specimens. The method of identifying a particular fossil depends on the details which it shows. The characters of echinoid fragments vary with the position of those fragments in the test. Fragments present a slightly more difficult problem than complete fossils, and different methods must be used in identifying them. For example, it is usually possible to assign a fragment of the unpaired ambulacrum to a certain genus because of the characteristic arrangement of the pores, or their shape. A fragment of a paired ambulacrum from this same genus may have to be identified by a much more difficult process, which includes elimination, as well as comparison. This particular fragment may be very similar to several others, and these others must be eliminated by a comparison of details which can only be seen when the various plates are studied together.

The first and most essential step in identifying any fragments of a macrofossil is to acquire a knowledge of the complete form in microscopic detail. It is necessary with echinoids to be thoroughly familiar with all parts of the test, so that any fragment may be assigned readily to a system of the corona, and to at least some approximate position in that system. When this has been done it is possible to make use of the generic and specific characters in identifying the fragment.

The first attempts at the identification of echinoid fragments were discouraging because so many of the pieces appeared to be similar or identical, although it was known that they must have come from different species, or even from different genera. Therefore, in order to make a beginning, indirect means of identification were used.

One useful method was to collect material from a stratigraphic level known to contain only a certain genus or species. In this manner any fragments found were reasonably sure to belong to that genus or species. After some practice fragments which previously had appeared identical showed differences. Similar methods can be used with echinoids that are not especially abundant or limited to a single zone.

Some individual echinoid tests are so poorly preserved, that they can be broken up with proper handling in much the same manner as they would be broken up by the usual processes of nature. The fragments can then be studied individually better than they could be when in place on the specimen. A fragment studied in this way often furnishes more information than the same fragment studied in place in the complete test.

A microscopic comparison of complete specimens that are similar to each other is often necessary. Two similar fragments sometimes cannot be told apart until complete examples

KEY TO GENERA

Large circular to ovoid pores in ambulacra
- Tubercles perforate and crenulate
  - Ambulacral plates contain no primary tubercles ..... Family CIDARIDAE
    - Pores connected by a ridge ..... *Dorocidaris*
    - Pores connected by a furrow ..... *Leiocidaris*
  - Ambulacral plates with one or more primary tubercles ..... Family PHYMATRESIDAE
    - One tubercle per ambulacral plate
      - Pore-pairs uniserial
        - One pore-pair per ambulacral plate ..... *Orthopsis*
        - Three pore-pairs per ambulacral plate
          - Line of pore-pairs slightly sinuous ..... *Pseudocidaris*
          - Line of pore-pairs not sinuous
            - Small, granules abundant ..... *Polydiadema*
            - Medium sized, granules not abundant ..... *Loriolia*
    - More than one tubercle per ambulacral plate
      - Pore-pairs uniserial ..... *Cottaldia*[3]
    - Pore-pairs biserial
      - One tubercle per ambulacral plate ..... *Tetragramma*
      - Two tubercles per ambulacral plate ..... *Echinopsis*
      - Three or more *non-crenulate* tubercles per ambulacral plate ..... *Micropedina*
    - Pore-pairs irregular but not biserial
      - One tubercle per ambulacral plate ..... *Leptarbacia*
- Tubercles imperforate
  - Tubercles crenulate or non-crenulate ..... Family OLOPHYMIDAE
    - Ambulacral plates with one mamillated, non-crenulate tubercle, plates compound ..... *Salenia*
    - Ambulacral plates with one primary crenulate tubercle, pores uniserial or alternate ..... *Phymosoma*
  - Tubercles non-crenulate
    - Tubercles not reduced in aboral plates
      - Ambulacral and interambulacral plates contain one tubercle each ..... *Goniopygus*
    - Tubercles reduced in aboral plates
      - Ambulacral and interambulacral plates contain more than one tubercle each ..... *Godiopsis*

Small circular pores in ambulacra
- Interporiferous area wide, pores on edge of plate
  - Tubercles scattered, no areola ..... *Holectypus*
  - Tubercles numerous, distinctly depressed circular areola ..... *Pyrina*, *Pseudopyrina*
- Interporiferous area narrow, pores toward center of the plate ..... *Porobrissus*

Pores short or linear slits; sometimes slightly ovoid; pores of unpaired ambulacrum different from those of the paired ambulacrum
- Ambulacral plates slightly convex or straight (ambulacra flush with surface of test) ..... Family ANANCHITIDAE
  - Pores of paired ambulacra short slits; pores of unpaired ambulacrum small, round, en chevron ..... *Holaster*
  - Pores of ambulacra slightly ovoid; inner pore less than half the size of outer pore of a pair ..... *Pseudananchys*
  - Pores of ambulacra rounded ..... *Echinocorys*[4]
- Ambulacral plates curved or concave ..... Families PROSPATANGIDAE AND BRISSIDAE
  - Pores of unpaired ambulacrum ovoid, either similar or of alternating lengths; anterior pore of pore-pairs from paired ambulacra much smaller than posterior pore ..... Family PROSPATANGIDAE
  - Pores of unpaired ambulacrum similar and separated by a tubercle ..... *Washitaster*
  - Pores of unpaired ambulacrum of alternate length; short pores separated by tubercle ..... *Heteraster*

[3] Although *Cottaldia* is not classified as belonging to this family, its perforate tubercles cause it to be placed in the key at this point.

[4] Based entirely on figures: no specimen or fragments available.

Pores of unpaired ambulacrum usually slits or only slightly ovoid, arranged on chevron; anterior pore of a pair from paired ambulacra not greatly reduced in size ..... Family BRISSIDAE

Pores of paired ambulacra linear; pores of unpaired ambulacrum slits on chevron; ambulacral plates little curved; interambulacral plates rather smooth ..... *Macraster*

Pores of unpaired ambulacra slit to ovoid; arranged en chevron and separated by a tubercle; plates curved or concave (ambulacra in grooves) ..... *Epiaster, Hemiaster, Proraster?*

of the species can be compared.

When practice and experience have been acquired by indirect methods of determination, it is possible to identify many forms directly without comparison or without knowledge of their horizon. Many fragments of forms can only be determined by the use of both methods.

The plates, or portions of the plates, are the parts which must be used almost exclusively in identification. Spines, although abundant, can not be used except occasionally, because otherwise radically different species have similar spines. Some spines are found in place, and these can be definitely assigned to their proper species, but this does not prove that similar spines *not in place* belong to the same species.

The general character of a fragment will often indicate its affinities immediately. A very smooth interambulacral fragment, for instance, can not belong to a *Heteraster*, *Washitaster*, *Tetragramma*, *Epiaster* or a *Cidarid:* but can be referred only to one of a few genera, such as *Holectypus*, *Holaster*, *Macraster*, *Hemiaster*, etc. The same applies to the general appearance of an ambulacral fragment, but other features exhibited by such fragments are more diagnostic. The detailed characters, such as the form of the tubercles, their number and arrangement in interambulacral plates, and the position of pores and their shape in ambulacral plates must be relied on to indicate the genus or species.

Family CIDARIDAE Gray

This family is characterized by sinuous ambulacra, the plates of which contain no primary tubercles. The height of the ambulacral plates is equal to about one-sixth of their width, but the height of an interambulacral plate is approximately the same as the width. The ambulacral plates contain no primary tubercles, but are the site of several "secondary" tubercles which structurally are rounded or oval "knobs." An interambulacral plate supports one primary perforate tubercle which is the major feature of the plate. The distinct areola is very characteristic for this family, and aids in separating its fragments from those of other families. The plates of the interambulacra are easily distinguished by their massive size. Spines from members of this family are of various types, but they are similar in general appearance. They are usually large and cylindrical, having broken longitudinal ridges.

Genus DOROCIDARIS A. Agassiz

The scrobicula is very deep, and the marginal granules are larger than

those covering the remainder of the interambulacral plate. The ambulacral pores are ovoid, tapering toward the center of the poriferous zone with pores of a pair connected by a slight ridge. The granules of an ambulacral plate are round "knobs" three to four in number and are located only between the pore-pairs and the median line of the ambulacral system. They lie in a horizontal line and increase slightly in size toward the pore-pair.

DOROCIDARIS TEXANUS (Clark)

Plate 17, figures 1–3, 8, 9

Cidaris texanus CLARK, *1891*, Johns Hopkins Univ. Circ., vol. 10, no. 87, p. 75; *1893*, Johns Hopkins Univ. Circ., vol. 12, no. 103, p. 61; *1893*, U. S. Geol. Survey, Bull. 97, pp. 36, 37, pl. 7, figs. 1*a–e*.—CLARK and TWITCHELL, *1915*, U. S. Geol. Survey, Mon. 54, p. 45, pl. 9, figs. 2*a–f*.

Dorocidaris texanus LAMBERT, *1927*, Bull. Soc. Géol. France, vol. 26, fasc. 3–5, p. 265; ADKINS, *1928*, Univ. Texas, Bull. 2838, p. 271.

Approximate size of plates from the ambital region: ambulacral plates height 0.4 mm., width 2.5 mm.; interambulacral plates, height 10.5 mm., width 15 mm.

Stratigraphic occurrence.—Washita group.

Genus LEIOCIDARIS Desor

The scrobicula is less pronounced than in *Dorocidarias*, and the marginal granules blend with those covering the remainder of the plate. The mamelon of a tubercle is rounded and more prominent than in *Dorocidaris*. In the ambulacral plates the outer pore of a pair is ovoid and tapers toward the mid-line of the poriferous zone, while the inner pore is circular. The pores of a pair are connected by a furrow. The granules in the ambulacral plates are round and oval knobs and lie in a horizontal line. There are three to five in a plate depending on the vertical position of the plate in the entire ambulacral system.

LEIOCIDARIS HEMIGRANOSUS (Shumard)

Plate 17, figures 4–7

Leiocidaris hemigranosus CLARK and TWITCHELL, *1915*, U. S. Geol. Survey, Mon. 54, p. 48, pl. 10, figs. 1*a–g*; pl. 11, figs. 1*a–b*, (See for complete synomyny up to 1915); ADKINS and WINTON, *1920*, Univ. Texas, Bull. 1945, p. 49, pl. 20, fig. 3; WINTON, *1925*, Univ. Texas, Bull. 2544, p. 57, pl. 13, fig. 2; LAMBERT, *1927*, Bull. Soc. Géol. France, vol. 26, fasc. 3–5, p. 265; ADKINS, *1928*, Univ. Texas, Bull. 2838, p. 271, pl. 14, fig. 2.

Approximate size of plates from the ambital region: ambulacral plates, height 0.44 mm., width 3.2 mm.; interambulacral plates, height 10.5 mm., width 11.2 mm.

Stratigraphic occurrence.—Upper Washita group (Denton-Grayson?).

Family PHYMATRESIDAE

This family differs from the Cidaridae, in that both ambulacral and interambulacral plates contain primary tubercles. It differs from the Olophymidae and Habrocidaridae since the tubercles of these two families are imperforate, while those of the Phymatresidae are perforate. No distinct scrobicula surrounds the tubercles, and the ambulacral plates are usually compound.

Genus PSEUDOCIDARIS Etallon

Resembles very much the members of the family Cidaridae but plates can be distinguished because of their small size and the appearance of a few semi-tubercled plates toward the peristomial region. The primary tu-

bercles are crenulate and perforate. The ambulacra as a whole are less sinuous than those of the Cidaridae. No fragments were studied.

Pseudocidaris elegans (Clark) the only representative of this genus in the Cretaceous of Texas occurs in the Trinity group.

Genus LORIOLIA Neumayr

The fragments of this genus can be distinguished from those of the other genera of the family Phymatresidae because the pore-pairs of the ambulacral plates are in a line, the ambulacral plates are simple, and both ambulacral and interambulacral plates contain one large, deeply crenulate, perforate tubercle. This particular combination of features characterizes the genus. *Loriolia* is reported to be very similar to a Fredericksburg form, *Polydiadema*, but no plates of the latter have been found and no complete form studied. The plates of *Polydiadema* would probably be smaller and the granules more numerous.

LORIOLIA TEXANA (Clark)

Plate 17, figures 10–14

Pseudodiadema texana CLARK and TWITCHELL, *1915*, U. S. Geol. Survey, Mon. 54, p. 55, pl. 18, figs. 1*a–i*. (See for complete synonomy up to 1915).

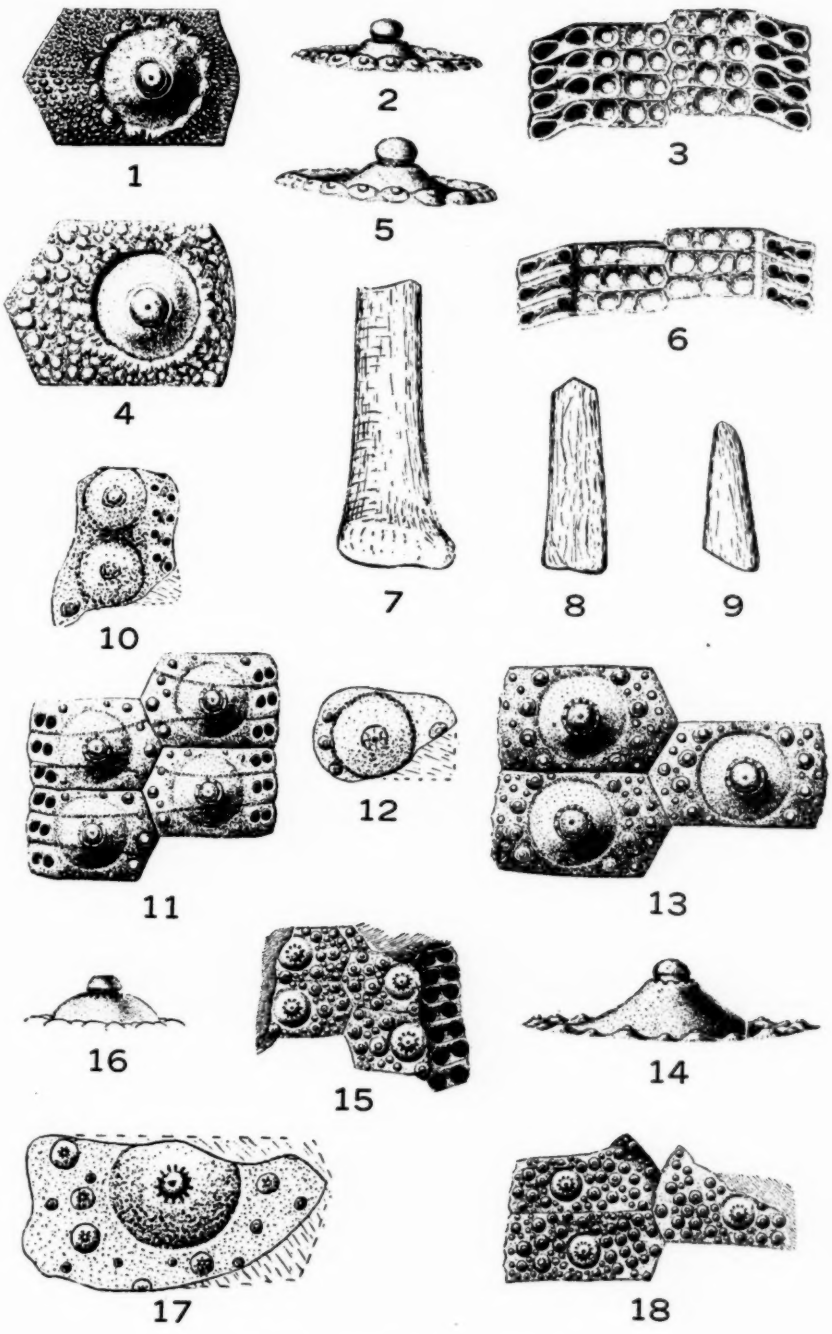
Loriolia texana LAMBERT, *1927*, Bull. Soc. Géol. France, vol. 26, fasc. 3–5, p. 266; ADKINS, *1928*, Univ. Texas, Bull. 2838, p. 273, pl. 1, figs. 6–7.

The complete test.—The test is small, circular and depressed, with the sides inflated, and upper and lower surfaces about equally flattened; the height is much less than the diameter. The ambulacra are narrow with two rows of primary tubercles. The pore-pairs are uniserial and located on the outside margin of each half-area.

Ambulacral plates.—Directly in the center of each ambulacral plate is located one primary tubercle. This tubercle is the most prominent feature of the plate. Near the outer margin of the ambulacral plate are located three pore-pairs, whose axes are slightly inclined, the inner pore lower than the outer. In a series of

EXPLANATION OF PLATE 17

FIGS. 1—*Dorocidaris texanus* (Clark), interambulacral plate, figure from Clark, U. S. Nat. Mus. 8381, type. Slightly enlarged.
2—Tubercle of same, figure from Clark, U. S. Nat. Mus. 8381, type. ×3.
3—Ambulacral plates of same, figure from Clark, U. S. Nat. Mus. 8381, type. ×6.
4—*Leiocidaris hemigranosus* (Shumard), interambulacral plate, figure from Clark, U. S. Nat. Mus. 21768.
5—Tubercle of same, figure from Clark, U. S. Nat. Mus. 21768. ×2.
6—Ambulacral plates of same, figure from Clark, U. S. Nat. Mus. 21768. ×5.
7—Spine of same, original (Denton formation). ×15.
8–9—*Dorocidaris?* spines, original (Denton formation). ×15.
10—*Loriolia texana* (Clark), ambulacral plates, original (Travis Peak formation). ×8.5.
11—Ambulacral plates of same, figure from Clark, U. S. Nat. Mus. 31197. ×8.
12—Interambulacral plate of same, original (Travis Peak formation). ×8.5.
13—Interambulacral plates of same, figure from Clark, U. S. Nat. Mus. 31197. ×8.
14—Tubercle of same, figure from Clark, U. S. Nat. Mus. 31197. ×12.
15—*Loriolia ornata* (Clark), ambulacral plates, figure from Clark, Johns Hopkins Univ. T3006, type. ×10.
16—Tubercle of same, figure from Clark, Johns Hopkins Univ. T3006, type. ×20.
17—Interambulacral fragment of same, original (Main Street formation). ×8.5.
18—Interambulacral plates of same, figure from Clark, Johns Hopkins Univ. T3006, type. ×10.



Smiser—Cretaceous echinoids

plates, this inclination of the axes of the pores may give a slightly sinuous appearance to the system. Secondary, non-perforate tubercles, and a few granules occur also, but these are concentrated along the median suture, the small tubercles seldom exceeding four in number. The ambulacral plate is only half the size of the interambulacral plate in the ambital region. Approximate size of ambulacral plate at ambitus: height 1.2 mm., width 1.8 mm.

Interambulacral plates.—These are simple and non-perforate, with one large primary tubercle directly in the center of the plate. This tubercle so completely covers the width of the plate, that all the secondaries are crowded to the inner and outer margins of the plate, with none at the top or bottom of the plate. About four secondary, non-perforate tubercles are located on each side of the primary tubercle, and among these are scattered granules. The primary tubercles of the interambulacral systems are slightly larger than those of the ambulacral systems. The interambulacral plates are about twice as large as the ambulacral plates, except near the apex and peristome, where their size becomes more nearly equal. Approximate size of interambulacral plates in the ambital region: height 1.4 mm., width 2.1 mm.

Tubercles and granules.—The primary tubercles, of which there are two rows in each system and hence one to each plate, are very prominent. Their areolas are circular, the bosses stout and prominent and the mamelons perforate. The areolas in the interambulacra are more deeply depressed than those in the ambulacra. The secondary tubercles are small rounded and mamillated knobs, which have no crenulations and are imperforate. The granules are very small, irregular, projections along the margins of the plates.

Stratigraphic occurrence.—This species occurs most commonly in the Glen Rose formation. Fragments have been found in the Travis Peak as well, but no complete specimens are reported from that formation.

LORIOLIA ORNATA (Clark)

Plate 17, figures 15–18

Heterodiadema ornata CLARK and TWITCHELL, *1915*, U. S. Geol. Survey, Mon. 54, p. 56, pl. 18, figs. 2*a–f;* LAMBERT and THIÉRY, *1909–25*, Essie de nomenclature raisonnée des échinides, p. 563.

Loriolia ornata LAMBERT, *1927*, Bull. Soc. Géol. France, vol. 26, fasc. 3–5, p. 266; ADKINS, *1928*, Univ. Texas, Bull. 2838, p. 273.

This species differs from *L. texana* in the shape of the tubercles, the bases of which are "swollen" in appearance, and in the fact that the plates also contain abundant secondary tubercles and granules, which are irregularly scattered over the surface. The boss of the tubercle rises abruptly from the test and has no surrounding areola. As figured by Clark and Twitchell, this form very closely resembles *Polydiadema texanum* (Roemer), and may even be identical with that form. One of Roemer's figures[5] of *Polydiadema texanum* is shown on Plate 18, and a comparison between this figure and that shown for *L. ornata* will readily reveal the

[5] Roemer, F., Die Kreidebildungen von Texas. Bonn 1852, Pl. 10, fig. 5.

similarity which exists between the two forms.

Stratigraphic occurrence.—Washita group.

Genus MICROPEDINA Cotteau

The primary tubercles are non-crenulate and less prominent than in the other genera of this family. There are two to three tubercles in ambulacral plates, and four to five in the interambulacral plates. The ambulacral plates contain four alternate pore-pairs, the pores of which are circular.

MICROPEDINA SYMMETRICA (Cragin)

Plate 18, figures 1, 2

Dumblea symmetrica CRAGIN, *1893*, Texas Geol. Surv. 4th Ann. Rept., p. 149, pl. 24, fig. 12; pl. 25, figs. 4–7; pl. 27, fig. 1; LAMBERT and THIÉRY, *1909–25*, Essai de nomenclature raisonnée des échinides, pp. 207–566.

Pedinopsis symmetrica CLARK and TWITCHELL, *1915*, U. S. Geol. Survey, Mon. 54, p. 64, pl. 23, figs. 1*a–h*.

Micropedina elisponensis FORBES, LAMBERT, *1927*, Bull. Soc. Géol. France, vol. 26, fasc. 3–5, p. 267.

Micropedina symmetrica ADKINS, *1928*, Univ. Texas, Bull. 2838, p. 276.

Approximate size of plates from ambital region; ambulacral plates, height 0.1 mm., width 4.4 mm. interambulacral plates, height 1.2 mm., width 6.4 mm.

Stratigraphic occurrence.—Duck Creek and Weno formations.

Genus TETRAGRAMMA

The ambulacral plates are compound and characterized by one large perforate tubercle and six pore-pairs, either alternate or biserial, with circular to oval pores. The interambulacral plates contain three to four tubercles, which decrease in size toward the outer margins of the plate.

TETRAGRAMMA STREERUWITZI (Cragin)

Plate 18, figures 3–5

Diplopodia streeruwitzi CRAGIN, *1893*, Texas Geol. Surv. 4th Ann. Rept., p. 147, pl. 24, fig. 2; pl. 25, figs. 9–10; CLARK and TWITCHELL, *1915*, U. S. Geol. Survey, Mon. 54, p. 58, pl. 20, figs. 3*a–c*; LAMBERT and THIÉRY, *1909–25*, Essai de nomenclature raisonnée des échinides, p. 88.

Tetragramma streeruwitzi LAMBERT, *1927*, Bull. Soc. Géol. France, vol. 26, fasc. 3–5, p. 266; ADKINS, *1928*, Univ. Texas, Bull. 2838, p. 274.

The complete test.—The test is subpentagonal, the upper surface somewhat convex and the lower surface flattened. The peristome is small and depressed. The apical opening is moderately large and distinctly five pointed.

Ambulacral plates.—Each ambulacral plate contains one primary tubercle which is perforate, and situated near the median line of the system. Six alternate pore-pairs lie on the outside margin of the plate, and cover fully one half of the plate. The pores are circular to ovoid. Ambulacral plates are compounded so that each pore-pair occupies a separate portion of the plate. Secondary tubercles and granules are concentrated near the median line of the ambulacral plate. Approximate size of plates at ambitus: height 1.5 mm., width 3.1 mm.

Interambulacral plates.—An interambulacral plate contains three primary perforate tubercles, the outside tubercles always smaller than those toward the median interambulacral suture. Granules surround the tubercles but usually form more or less vertical rows between the tubercle. This species contains one less tubercle per interambulacral plate than *T. taffi*, and one more per interambu-

lacral plate than *T. hilli*. Approximate size of plates at ambitus: height 1.3 mm., width 4.5 mm.

Tubercles and granules.—The tubercles of this form are important since they separate it from a very similar form, *Phymosoma texanum*. The tubercles of the latter are imperforate, while those of *T. streeruwitzi* are perforate. The tubercles of *T. streeruwitzi* are "swollen" rather than depressed and have on the whole a smoothly rounded appearance. Granules are few, sometimes replaced by numerous smaller tubercles.

Stratigraphic occurrence.—Washita group.

Genus Polydiadema

This genus is distinguished from *Loriolia* by smaller size and more abundant granules, plus the fact as shown only on nearly complete specimens, that the apical system opening lacks the lateral incision.

Polydiadema texanum (Roemer)

Plate 18, figures 6–7

Diadema texanum Roemer, *1852*, Die Kreidebildungen von Texas. Bonn, p. 83, pl. 10, fig. 5.

Trochotiara texanum Lambert and Thiéry, *1909–25*, Essai de nomenclature raisonnée des échinides, p. 183.

Polydiadema texanum, Lambert, *1927*, Bull. Soc. Géol. France, vol. 26, fasc. 3–5, p. 266; Adkins, *1928*, Univ. Texas, Bull. 2838, p. 275.

As mentioned in connection with *Loriolia ornata*, *Polydiadema texanum* appears similar if not identical with that form. Although the lateral incision of the apical opening is not so pronounced in Roemer's figure of *P. texanum*, it is present, as a close examination of the figure will show. No other difference, save the reported size of the two forms, seems to exist.

Stratigraphic occurrence.—Fredericksburg group.

Genus Leptarbacia Clark

The interambulacral plates of this genus contain three or more crenulate tubercles, the largest one of which is located directly in the center of the plate. Toward the apical system all tubercles except the large central one disappear, leaving a single row of tu-

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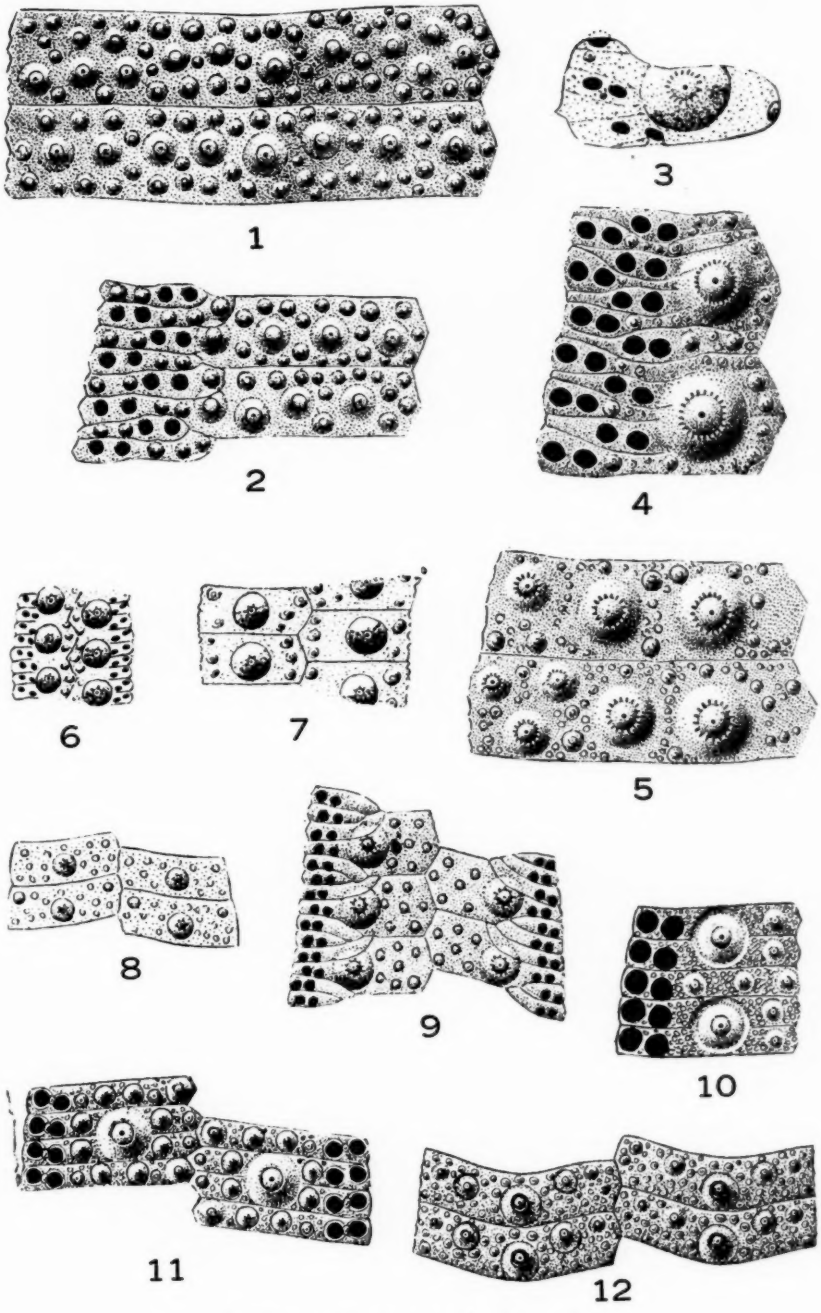
Explanation of Plate 18

Figs. 1—*Micropedina symmetrica* (Cragin), interambulacral plates, figure from Clark, Texas Geol. Survey type. ×8.
2—Ambulacral plates of same, figure from Clark, Geol. Survey Texas, type. ×8.
3—*Tetragramma streeruwitzi* (Cragin), ambulacral fragment, original (Main Street formation). ×8.5.
4—Ambulacral plates of same, figure from Clark, Texas Geol. Survey, type. ×8.
5—Interambulacral plates of same, figure from Clark, Texas Geol. Survey, type. ×8.
6—*Polydiadema texanum* (Roemer), ambulacral plates, figure drawn after Roemer. slightly enlarged.
7—Interambulacral plates of same, figure drawn after Roemer. Slightly enlarged.
8—*Leptarbacia arguta* Clark, interambulacral plates, figure from Clark, Johns Hopkins Univ. T3004, type. ×4.
9—Ambulacral plates of same, figure from Clark, Johns Hopkins Univ. T3004, type. ×15.
10—*Orthopsis planulata* Clark, ambulacral plates, figure from Clark, Johns Hopkins Univ. 73005, type. ×6.
11—*Orthopsis occidentalis* Cragin, ambulacral plates, figure from Clark, Texas Geol. Survey, type. ×6.
12—Interambulacral plates of same, figure from Clark, Texas Geol. Survey, type. ×3.



Smiser—Cretaceous echinoids

bercles in each half of the interambulacral system. The ambulacral plates are characterized by five alternate pore-pairs, the pores of which are small, circular and closely spaced.

LEPTARBACIA ARGUTA Clark

Plate 18, figures 8, 9

Leptarbacia arguta CLARK and TWITCHELL, *1915*, U. S. Geol. Survey, Mon. 54, p. 53, pl. 16, fig. 1; LAMBERT and THIÉRY, *1909–25*, Essai de nomenclature raisonnée des échinides, p. 565; Lambert, *1927*, Bull. Soc. Géol. France, vol. 26, fasc. 3–5, p. 266; ADKINS, *1928*, Univ. Texas, Bull. 2838, p. 275.

Approximate size of plates from the ambitus: ambulacral plates, height 0.4 mm., width 1 mm.; interambulacral plates, height 1 mm., width 3.2 mm.

Stratigraphic occurrence.—Washita group.

Genus ECHINOPSIS

The tubercles are crenulate and perforate, and distributed one to each ambulacral plate, and three to each interambulacral plate except near the peristome and apex.

Echinopsis lineatus (Clark) is the sole representative of the genus in the Texas Cretaceous and occurs in the Grayson formation.

Genus ORTHOPSIS

The primary tubercles are noncrenulate but perforate. Each interambulacral plate carries one large primary tubercle slightly below the center of the plate. On each side is one smaller tubercle set somewhat higher in the plate. Ambulacral plates are peculiarly compounded, with the pore-pairs in a line, the pores of a pair circular and separated by a large granule. Each ambulacral plate contains one pore-pair, but the one primary tubercle is divided between two plates, so that it stands opposite two pore-pairs.

ORTHOPSIS OCCIDENTALIS Cragin

Plate 18, figures 11, 12

Orthopsis occidentalis CRAGIN, *1893*, Texas Geol. Surv. 4th Ann. Rept., pp. 160–161, pl. 25, figs. 1–3; pl. 27, fig. 2; CLARK and TWITCHELL, *1915*, U. S. Geol. Survey, Mon. 54, p. 54, pl. 17, figs. 1*a–g*; LAMBERT and THIÉRY, *1909–25*, Essai de nomenclature raisonnée des échinides, p. 200; LAMBERT, *1927*, Bull. Soc. Géol. France, vol. 26, fasc. 3–5, p. 266; ADKINS, *1928*, Univ. Texas, Bull. 2838, p. 276.

No tubercle between the pores of a pore-pair. Approximate size of plates from the ambitus: ambulacral plates, height 0.5 mm., width 3.1 mm.; interambulacral plates, height 0.83 mm., width 3.5 mm.

Stratigraphic occurrence.—Washita group.

ORTHOPSIS PLANULATA Clark

Plate 18, figure 10

Orthopsis planulata CLARK and TWITCHELL, *1915*, U. S. Geol. Survey, Mon. 54, p. 54, pl. 16, figs. 2*a–c*; ADKINS, *1928*, Univ. Texas Bull. 2838, p. 276.

Tubercle separating the pores of each pore-pair. Approximate size of plates from the ambitus: ambulacral plates, height 0.45 mm., width 3 mm.; interambulacral plates, height 0.75 mm., width 3.4 mm.

Family OLOPHYMIDAE Lambert and Thiéry

This family is marked by its nonperforate tubercles which are usually crenulate when located on interambulacral plates, and are only noncrenulate mamillated granules on ambulacral plates. The pore-pairs of the ambulacral plates are in a line and the

pores of a pair are circular. The ambulacral plates are usually very indistinctly compounded.

Genus SALENIA

Interambulacral plates are characterized by one very prominent, non-perforate, crenulate tubercle, with granules concentrated toward the inner margin of the plate. A scrobicula surrounds the tubercle, but is not always prominent enough to be distinctive. The height of both interambulacral plates and ambulacral plates nearly equals the width in each case, but from plates near the apex the height of the plates slightly exceeds the width.

Ambulacral plates are characterized by one mamillated granule which is a great deal smaller than even the secondary tubercles of the interambulacral plates, and is non-perforate and non-crenulate. The pores of a pair are nearly circular, and the inner pore of each pair is sometimes divided between two parts of the compound plate. Granules of the ambulacral system are concentrated along the median suture.

SALENIA TEXANA Credner

Plate 19, figures 1–6

Salenia texana CLARK and TWITCHELL, *1915*, U. S. Geol. Survey, Mon. 54, p. 49, pl. 12, figs. 1*a–i;* pl. 14, figs. 1*a–c;* LAMBERT, *1927*, Bull. Soc. Géol. France, vol. 26, fasc. 3–5, p. 267; ADKINS, *1928*, Univ. Texas, Bull. 2838, p. 277.

Lambert considers this form as a variety of *S. prestensis* and considers *S. prestensis* identical with *S. mexicana*. He does not believe the differences are sufficient to warrant a new species.

The complete test.—The test is concave in the region of the peristome and convex toward the apex. The sides are inflated giving a somewhat globose appearance. The plates of the apical system form a hard convex cap which covers the top portion of the test. The peristome is relatively large.

Ambulacral plates.—Each ambulacral plate carries one mamillated granule and three pore-pairs. The bulk of the granules of a plate are located between the mamillated granule and the inside edge of the plate. The plates of the ambulacra are peculiarly compounded, so that they include three parts, each part being the site of one full pore and one half-pore. The middle part carries the mamillated granule and one full pore plus two half-pores. The axes of the pore-pairs are inclined slightly so that it is always the inside pore of a pair which is divided between two parts of the compound plate. An elevated portion of the test resembling a granule separates the pores of a pair. Approximate size of ambulacral plates from ambitus: height 1.3 mm., width 1.5 mm.

Interambulacral plates.—One large primary, non-perforate tubercle occupies the center of each interambulacral plate. A few mamillated granules occur on the outer edge of the plate but are, as a rule, concentrated along the inner margin of the plate. The interambulacral plates from this species are very large compared to the size of the complete individual and consequently the larger plates are slightly curved. The scrobicula surrounding the primary tubercles is

distinguishable but not so marked as in the members of the family Cidaridae. Approximate size of interambulacral plates from the ambitus: height 4 mm., width 4.2 mm.

Tubercles and granules.—Primary tubercles are imperforate and crenulate. The secondary tubercles are in the form of mamillated granules, which vary greatly in size. Toward the apical system the primary tubercles become replaced by large, non-perforate, non-crenulate, mamillated granules.

Stratigraphic occurrence.—Fredericksburg and Washita groups.

SALENIA VOLANA Whitney

Salenia volana WHITNEY, *1916*, Bull. Am. Paleontology, no. 26, vol. 5, p. 4, pl. 1, figs. 1–9, LAMBERT, *1927*, Bull. Soc. Géol. France, vol. 26, fasc. 3–5, p. 267, ADKINS, *1928*, Univ. Texas, Bull. 2838, p. 278.

This species doubtless cannot be distinguished by fragments. No specimens or detailed figures were available but the form is stated to differ from *S. texana* as follows: "It is less elevated; has fewer ambulacral and interambulacral plates; interambulacral lips of peristome straight, instead of bilobate; periproct of different shape. It differs from *S. mexicana* in being more depressed, and in having 16 ambulacral tubercles instead of 20. It differs from *S. prestensis* in having five instead of seven interambulacral plates."[6] These differences would not be shown in the usual fragments.

Stratigraphic occurrence.—Lower part of the Buda formation.

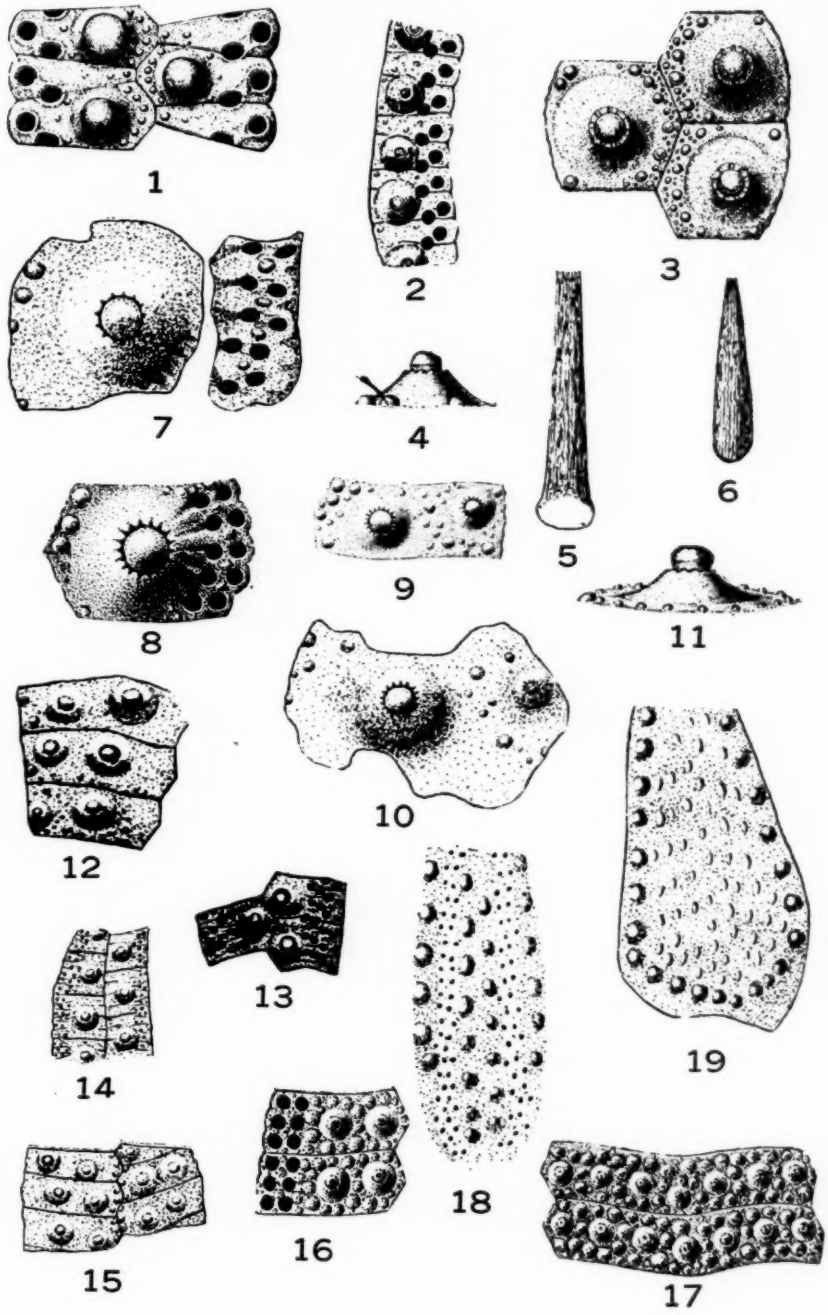
Genus PHYMOSOMA

This genus is differentiated from *Salenia* by the tubercles which are

[6] Adkins, W. S., Handbook of Texas Cretaceous Fossils: *Texas Univ. Bull.* 2838, p. 278.

EXPLANATION OF PLATE 19

FIGS. 1—*Salenia texana* Credner, ambulacral plates, figure from Clark, U. S. Nat. Mus. 8329, specimen A. ×10.
2—Ambulacral plates of same, original (Goodland formation). ×8.5.
3—Interambulacral plates of same, figure from Clark, U. S. Nat. Mus. 8329, specimen A. ×3.
4—Tubercle of same, figure from Clark, U. S. Nat. Mus., specimen A. Enlarged.
5–6—*Salenia?* spines, original (Goodland formation). ×15.
7—*Phymosoma texanum* (Roemer), ambulacral plate, original (Goodland formation). ×8.5.
8—Ambulacral plate of same, figure from Clark, U. S. Nat. Mus. 9838. ×8.
9—Interambulacral plate of same, figure from Clark, U. S. Nat. Mus. 9838. ×3.
10—Interambulacral fragment of same, original (Goodland formation). ×8.5.
11—Tubercle of same, figure from Clark, U. S. Nat. Mus. 9838. ×10.
12—*Phymosoma mexicanum* Böse, interambulacral plates, drawn and enlarged from the complete specimen figured by Böse.
13—Ambulacral plates of same, figure from same source.
14—*Phymosoma volanum* (Cragin), ambulacral plates, drawn and enlarged from the complete specimen figured by Whitney.
15—Interambulacral plates of same, figure from same source.
16—*Cottaldia rotula* (Clark), ambulacral plates, figure from Clark, Johns Hopkins Univ. T3007, type. ×10.
17—Interambulacral plates of same, figure from Clark, Johns Hopkins Univ. T3007, type. ×10.
18—Genus *Codiopsis*, ambulacrum, figure after Lambert. Enlarged.
19—Interambulacrum of same, figure after Lambert. Enlarged.



Smiser—Cretaceous echinoids

imperforate but crenulate, both in ambulacral plates and interambulacral plate. It also has more than one tubercle per interambulacral plate. The boss of the tubercle has a "swollen" appearance and the mamelon is set deep within the crenulated portion of the boss. This genus differs from a very similar genus, *Tetragramma* (family Phymatresidae), in that the tubercles of *Phymosoma* are not perforate, and the tubercles of *Tetragramma* are perforate.

PHYMOSOMA TEXANUM (Roemer)

Plate 19, figures 7–11

Cyphosoma texanum CLARK and TWITCHELL, *1915*, U. S. Geol. Survey, Mon. 54, p. 60, pl. 21, figs. 1*a–g*. (See for complete synonomy up to 1915).

Phymosoma texanum LAMBERT, *1927*, Bull. Soc. Géol. France, vol. 26, fasc. 3–5, p. 268; ADKINS, *1928*, Univ. Texas, Bull. 2838, p. 278. See also WINTON, *1925*, Univ. Texas, Bull. 2544, pl. 12, fig. 9 (as *Cyphosoma*).

The complete test.—The test is large and subcircular with the sides inflated. The upper surface is slightly convex, the lower surface nearly flat. The peristome is wide, about two-fifths the diameter of the test, with distinct branchial incisions. The periproct is large and subpentagonal.

Ambulacral plates.—The ambulacral plates contain one primary tubercle and four to six pore-pairs depending on the vertical position of the plate in the ambulacral system. Ambulacral plates between the ambitus and peristome contain four pore-pairs arranged in line along the outer margin of the plate. Plates from between the ambitus and apex contain five to six pore-pairs (commonly six) arranged alternately along the outer margin of the plate. Granules occur along the inner edge of each plate. The pores are circular and very closely spaced. Approximate size of ambulacral plates from the ambitus: height 1.5 mm., width 2.5 mm.

Interambulacral plates.—Each interambulacral plate contains two tubercles which become reduced to one at the apex. The tubercle nearest the median suture line is the larger, and is the one which persists to the apical system. The larger tubercle is considerably lower in the plate than the smaller. Approximate size of interambulacral plates from the ambitus: height 1.8 mm., width 5 mm.

Tubercles and granules.—The tubercles are imperforate but crenulate, with a smooth rounded boss into the crenulate top of which is set a round mamelon. The granules are all small and never mamillated.

Stratigraphic occurrence.—Comanche Peak and Lower Goodland formations.

PHYMOSOMA MEXICANUM Böse

Plate 19, figures 12, 13

Phymosoma mexicanum BÖSE, *1910*, Bol. Inst. Geol. Mex., no. 25, p. 158, pl. 33, figs. 7–10; pl. 54, fig. 3; pl. 35, figs. 1–3, 7, 8; ADKINS, *1928*, Univ. Texas, Bull. 2838, p. 279.

The figures by Böse illustrating this form show it to be identical with *P. texanum*, except that the pore-pairs are alternate to biserial and that the four rows of tubercles present in the interambulacral systems of both forms at the ambitus become restricted to one row at the apex in *P. texanum* while in *P. mexicanum* the four rows persist nearly to the apex, the outer tubercles becoming much smaller, and finally only two tuber-

cles remain, one being very small.

Stratigraphic occurrence.—Fort Worth-Denton formations.

PHYMOSOMA VOLANUM (Cragin)

Plate 19, figures 14, 15

Cyphosoma volanum CLARK and TWITCHELL, *1915*, U. S. Geol. Survey, Mon. 54, p. 61, pl. 21, figs. 2*a–b*, 3 (See for complete synonomy up to 1915); WHITNEY, *1916*, Bull. Am. Paleontology, no. 26, vol. 5, p. 11, pl. 6, fig. 1.

Phymosoma volanum LAMBERT, *1927*, Bull. Soc. Géol. France, vol. 26, fasc. 3–5, p. 268; ADKINS, *1928*, Univ. Texas, Bull. 2838, p. 279.

Distinguished from *P. texanum* and *P. mexicanum* by its pore-pairs being uniserial nearly to the peristome, and then not distinctly biserial or alternate, but merely crowded.

Stratigraphic occurrence.—Upper Washita group and upper Buda formation.

Genus COTTALDIA Desor

(COTTEAUDIA Lambert)

COTTALDIA? ROTULA Clark

Plate 19, figures 16, 17

Cottaldia rotula CLARK and TWITCHELL, *1915*, U. S. Geol. Survey, Mon. 54, pl. 57, pl. 20, figs. 1*a–d;* WHITNEY, *1916*, Bull. Am. Paleontology, no. 26, vol. 5, p. 8, pl. 4, figs. 1–10; pl. 5, figs. 1–2.

Cottaldia (?) *rotula* ADKINS, *1928*, Univ. Texas, Bull. 2838, p. 279, pl. 23, fig. 3.

This species described and figured by Clark shows more of the characters of the family Phymatresidae in the sharp outlines of the tubercles and their perforate mamelons.

The complete test.—The test is small, subhemispherical, with slightly convex upper surface and concave lower surface. The apical system and peristome are small.

Ambulacral plates.—Ambulacral plates are small with three pore-pairs arranged in a line, and two primary tubercles per plate. The plates are very rough and conspicuously granuled. Approximate size of ambulacral plates from the ambitus: height 0.6., mm., width 1.4 mm.

Interambulacral plates.—Each plate is slightly bent with a horizontal line of six to seven primary tubercles which are little larger than the surrounding secondaries and granules. Approximate size of interambulacral plates from the ambitus: height 0.6 mm., width 2.9 mm.

Tubercles and granules.—The primary tubercles are sharp in outline, with non-crenulate boss and perforate mamelon. The granules are large and extremely numerous.

Stratigraphic occurrence.—Buda formation.

Family HABROCIDARIDAE Lambert and Thiéry

This family differs from the preceding family in that the primary tubercles are neither crenulate nor perforate. The plates are compound but the pore-pairs are uniserial, except near the peristome, where they are polyserial. Tubercles and granules are decidedly more abundant below than above the ambitus.

Genus CODIOPSIS

Plate 19, figures 18, 19

A comparatively rare genus which doubtless cannot be recognized by fragments unless the fragments found are large enough to show some features of the complete fossil. The genus is marked by a concentration

of tubercles and granules on the oral surface of the test, the region from the ambitus to the apex supporting only occasional mamillated tubercles. From figures of this genus shown by Lambert[7] and by Whitney[8] the pore-pairs of the ambulacra are uniserial near the apex but toward the ambitus become slightly alternate but never biserial.

Specific determinations from small fragments is impossible and due to the scarcity of the form it is not important. Two species have been described from Texas.

CODIOPSIS TEXANUS Whitney

Codiopsis texanus WHITNEY, *1916*, Bull. Am. Paleontology, no. 26, vol. 5, p. 7, pl. 3, figs. 1–4; pl. 6, fig. 2.

Stratigraphic occurrence.—Lower Buda formation.

CODIOPSIS sp. aff. VALOTAIREI Lambert

Codiopsis sp. aff. valotairei ADKINS, *1928*, Univ. Texas, Bull. 2838, p. 280.

Stratigraphic occurrence.—Lower Austin formation.

Genus GONIOPYGUS Zittel

The tubercles are non-crenulate and imperforate, located one to each ambulacral and interambulacral plate. The pore-pairs are uniserial, crowded in the ambulacral plates surrounding the peristome. Tubercles appear in plates both above and below the ambitus, but granules are concentrated in the plates below the ambitus.

[7] Lambert, J., Note sur un *Codiopsis* noveau de la craie de Tourraine: *Bull. Soc. Géol. France*, (4), vol. 3, Pl. 3, figs. 12–17.

[8] Whitney, F. L., Echinoidea of the Buda Limestone: *Bull. Am. Paleontology*, no. 26, vol. 5, pl. 17, figs. 1–4: pl. 20, fig. 2.

GONIOPYGUS ZITTELI Clark

Plate 20, figures 1–4

Goniopygus zitteli CLARK and TWITCHELL, *1915*, U. S. Geol. Survey, Mon. 54, p. 52, pl. 14, figs. 3*a–c;* pl. 15, figs. 1*a–h* (See for complete synonomy up to 1915); LAMBERT, 1927, Bull. Soc. Géol. France, vol. 26, fasc. 3–5, p. 268; ADKINS, *1928*, Univ. Texas, Bull. 2838, p. 280.

The complete test.—The test is subconical and circular with elevated upper surface and flattened base. Apical system prominent and compact, with elongate plates. Peristome large, half the diameter of the test, with indistinct branchial incisions.

Ambulacral plates.—Each ambulacral plate is marked by one primary tubercle, and few if any granules. This lack of granules separates the ambulacral plates of this form distinctly. A few granules occur along the inner margin of an ambulacral plate from below the ambitus, but seldom exceed three in number. The outer edges of the ambulacral plates are very indistinctly compounded into four parts, each part supporting one pore-pair, the axis of which is inclined so that the inner pore is lower than the outer and bisected by one of the compounding sutres. The pore-pairs become crowded near the peristome. Approximate size of ambulacral plates from the ambitus: height 2.2 mm., width 3.5 mm.

Interambulacral plates.—The plates above the ambitus contain one central primary tubercle with no granules. Below the ambitus granules surround the central tubercle but are concentrated toward the outer margin of the plate. Those along the inner margin are regularly arranged in a row along the zig-zag median suture.

This characteristic is peculiar to this genus since in other forms any conspicuous concentration of granules is along the median suture. Approximate size of interambulacral plates from the ambitus: height 2.2 mm., width 4.5 mm.

Tubercles and granules.—The tubercles are very prominent but are non-crenulate, and imperforate with a suggestion of a sunken areola. Granules are fairly large, nearly all the same size and relatively sparse.

Stratigraphic occurrence.—Edwards formation.

GONIOPYGUS BUDAENSIS Whitney

Goniopygus budaensis WHITNEY, *1916*, Bull. Am. Paleontology, no. 26, vol. 5, p. 6, pl. 2, figs. 1–8; ADKINS, *1928*, Univ. Texas, Bull. 2838, p. 280.

Apparently differs from *G. zitteli* only in size and other minor features not shown on fragmental remains.

Stratigraphic occurrence.—Buda formation.

Family PYGASTERIDAE Lambert

This family is represented by only one genus in the Texas Cretaceous, but the genus includes numerous very similar species which are difficult to differentiate in complete specimens.

Genus HOLECTYPUS Desor

Plate 20, figures 5–11

The members of this genus are marked by very smooth ambulacral and interambulacral plates. Plates from above the ambitus seldom contain more than one or two very small tubercles, the details of which can only be seen with a microscope. Below the ambitus tubercles are larger and much more numerous and are surrounded by a more or less "square" areola. This peculiar appearance is due to the fact that the areola extends to the edges of the plate and is suddenly cut off. The tubercles are closely spaced in a horizontal line, the last tubercles toward the outer edge of the plate deviating slightly from the horizontal. The ambulacral plates are simple above but compound below the ambitus. The horizontal dimensions of plates from either system is markedly greater than the height of the plate. In interambulacral plates the width is four to five times the height, and in ambulacral plates seven to eight times. The tubercles are mamillated, crenulate and perforate.

It has been impossible definitely to differentiate the numerous species of this genus solely by the use of fragments, except in a few exceptional cases. From the viewpoint of the fragments there may be designated two general groups which can be determined, based on the relative size of the different species.

Holectypus engerrandi Lambert, *H. planatus* Roemer and *H. planus* Giebel are small forms, the ambulacral plates from the region of the ambitus being less than 2 mm. wide, interambulacral plates less than 4 mm. wide.

Holectypus limitis Böse, *H. transpecoensis* Cragin, *H. castilloi* Cotteau and *H. charlatoni* Cragin are larger forms in which ambulacral plates from the ambitus are 3 mm. or more wide, and interambulacral plates from the same region 6 mm. or more wide.

A key given by Adkins[9] is extremely useful in differentiating species in the complete form.

Stratigraphic occurrence.—The species of the genus *Holectypus* range from the Glen Rose formation of the Trinity group to the Grayson formation of the Washita group. *Holectypus engerrandi* Lambert occurs in the Glen Rose formation; *H. planatus* Roemer in the Fredericksburg and Washita groups; *H. planatus* Giebel in the Fredericksburg?; *H. transpecosensis* Cragin in the Washita group; *H. limitis* Böse in the upper Washita group; *H. castilloi* Cotteau occurs in the upper Georgetown formation and *H. charltoni* Cragin in the Main Street and Grayson formations.

[9] Adkins, W. S., Handbook of Texas Cretaceous Fossils: *Texas Univ. Bull.* 2838, p. 281.

HOLECTYPUS CASTILLOI Cotteau

Plate 20, figure 5

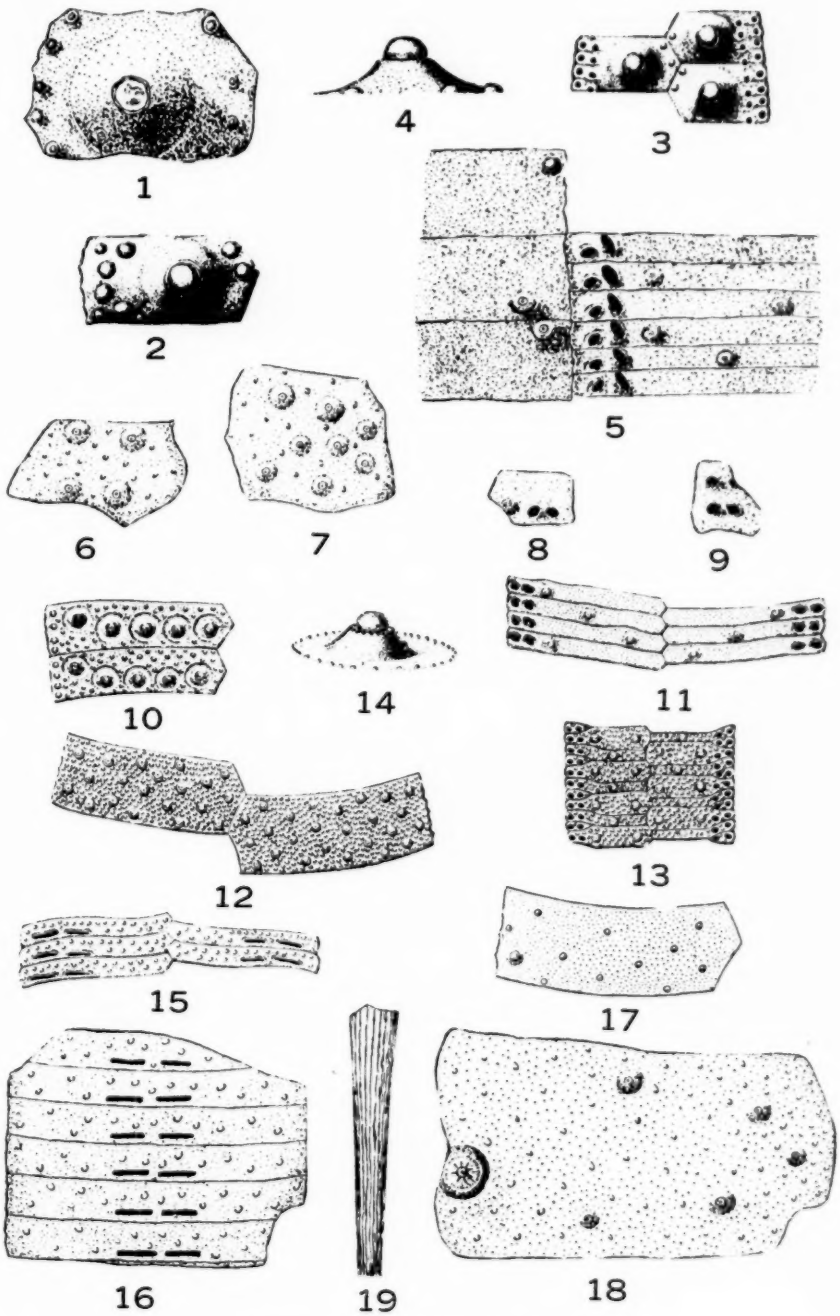
Holectypus castilloi COTTEAU, *1890*, Bull. Soc. Géol. France, ser. 3, vol. 18, p. 295, pl. 1, figs. 1–8.

This form has not been described from the Texas Cretaceous but is given by Adkins as a species which probably occurs in the Texas Comanchean. The single specimen which the writer has was collected from the upper Georgetown formation near Belton, Texas, by the Geology Department at Texas Christian University and placed in its museum labeled as an undescribed *Holectypus*. It has been placed in the writer's hands for description, and a small portion of the test is figured.

Description.—The test is large, tall, subpentagonal. The upper surface is subconical, not pointed at the apex.

EXPLANATION OF PLATE 20

FIGS. 1—*Goniopygus zitelli* Clark, interambulacral plate, original (Fort Worth formation). ×8.5.
2—Interambulacral plate of same, figure from Clark, U. S. Nat. Mus. 12234, type. ×4.
3—Ambulacral plates of same, figure from Clark, U. S. Nat. Mus. 12234, type. ×3.
4—Tubercle of same, figure from Clark, U. S. Nat. Mus. 12234, type. ×10.
5—*Holectypus castilloi* Cotteau, portion of an ambulacrum, original, drawn and enlarged from a complete specimen (Upper Georgetown formation). ×8.5.
6–7—*Holectypus limitis* Böse, interambulacral fragments, original (Lower Main Street formation). ×8.5
8–9—Ambulacral fragments of same, original (Lower Main Street formation). ×8.5
10—*Holectypus engerrandi* Lambert, interambulacra plates from lower surface of test, figure from Clark, U. S. Nat. Mus. figured specimen A (as *H. planatus*). ×3.
11—Ambulacral plates of same, figure from Clark, U. S. Nat. Mus. figured specimen A (as *H. planatus*). ×5.
12—*Pseudopyrina parryi* (Hall), interambulacral plates, figure from Clark, U. S. Nat. Mus. 9854. ×3.
13—Ambulacral plates of same, figure from Clark, U. S. Nat. Mus. 9854. ×5.
14—*Holaster simplex* Shumard, tubercle, figure from Clark, U. S. Nat. Mus. 8382, figured specimen A. ×10.
15—Ambulacral plates of same, figure from Clark, U. S. Nat. Mus. 8382, figured specimen A. ×3.
16—Ambulacral plates of same, original (Fort Worth formation). ×8.5.
17—Interambulacral plate of same, figure from Clark, U. S. Nat. Mus. 8382, figured specimen A. ×3.
18—Interambulacral plate of same, original (Fort Worth formation). ×8.5.
19—Spine of same, original (Fort Worth formation). ×15.



Smiser—Cretaceous echinoids

The lower surface is quite concave and this concavity is rather abruptly accentuated in the region of the peristome. The peristome is subcircular with a few of the branchial incisions visible. It is located in the sunken middle of the lower surface of the test. The periproct is small, elliptical, located in the outer half of the radius and somewhat pointed at both ends. The apical plates are not preserved.

The ambulacral areas are straight, widest at the ambitus, narrowing gently toward the apex and abruptly toward the peristome. The pore-pairs are along the outer margins of the ambulacral areas and are uniserial. Below the ambitus a small subgranule separates the pores of a pair. The pores are small, nearly circular, and very closely spaced, which leaves a relatively wide interporiferous zone in the middle of each ambulacral area. This space is filled by very small regularly arranged tubercles which rise to form three broken rows in each half area. As seen on the figure illustrating this form, the tubercles are located one to each ambulacral plate, but differing in position from plate to plate, so that there are three types of plates: (1) one with the tubercle near the median edge; (2) next, with tubercle in middle; and (3) last with tubercle near the pore-pair. By repetition of these three types of plates, three rows of tubercles are formed, the tubercles in a row occurring in every third plate. Below the ambitus the tubercles are better developed and more numerous, but the arrangement is nearly the same except for considerable crowding toward the peristome. At the ambitus the ambulacral zone is 6.5 mm. wide, each plate approximately 3.2 mm.

The interambulacral areas are large with very small indistinct tubercles above the ambitus but numerous better developed tubercles below the ambitus. At the ambitus there are about 24 rows of tubercles which decrease to two rows at the apex and to two or three rows at the peristome. The tubercles are arranged in a horizontal line, the outer tubercles of which deviate slightly from the horizontal. The interambulacral plates are slightly curved, with the central portion of the plate lower than the same point on the edges of the plate. At the ambitus the interambulacral zone is 22 mm. wide, each plate approximately 11 mm.

The tubercles are crenulate and perforate, and better developed on the lower surface, where a subscrobicula is developed around the tubercle.

Related forms.—Undoubtedly this form is extremely close to *H. charltoni* Cragin but differs from that form in the shape of the periproct. The periproct of *H. charltoni* as figured by Cragin[10] is rounded on the inner end. Böse[11] makes the following statement concerning these two very similar species: "*Holectypus castilloi* resembles not a little *H. charltoni* Cragin. It has the form and the size of the first species, the number of

[10] Cragin, F. W., A Contribution to the Invertebrate Paleontology of the Texas Cretaceous: *Texas Geol. Survey*, 4th Ann. Rept., p. 158, pl. 24, figs. 8–9, 1893.

[11] Böse, Emil, Geológica y Paleontológica del Cerro de Muleros: *Bol. Inst. Geol. Mex.*, no. 25, p. 161, 1910.

tubercles is probably the same, the position of the periproct is the same, the only difference being in the shape of the periproct; but the description and the figures given by Cragin are not sufficient to establish exactly the limit of the species."

Stratigraphic occurrence.—Upper Georgetown formation.

Cotteau in his original description gives only the locality as Jalpa (Jalisco) Mexico. Regarding its occurrence in Mexico Böse[12] states as follows: "Of *H. castilloi*, whose original happens to be in our hands, we do not know the horizon, because the locality has not yet been geologically studied."

Family Conulusidae

Only one genus of this family occurs in the Texas Cretaceous and it is not common.

Genus Pyrina Desmoulins

This genus is similar to the genus *Holectypus*, except that the tubercles and granules are very numerous. The tubercles are crenulate and perforate, and are surrounded by a very deep, circular, areola. The areola is quite distinctly incised, making the fragments recognizable and distinct from the very similar *Holectypus*.

Pyrina inaudita Böse

Pyrina inaudita Böse, *1910*, Bol. Inst. Geol. Mex. no. 25, p. 162, pl. 38, figs. 3–8; pl. 39, 1, 2, 4; Lambert and Thiéry, *1909–25*, Essai de nomenclature raisonnée des échinides, p. 576; Adkins, *1928*, Univ. Texas, Bull. 2838, p. 283.

[12] Böse, Emil, Geológica y Paleontológica del Cerro de Muleros: *Bol. Inst. Geol. Mex.* no. 25, p. 161, 1910.

Stratigraphic occurrence.—Fort Worth-Denton formations.

Family Echinoneidae Agassiz

Plate 20, figures 12, 13

The members of this family occurring in the Texas Cretaceous belong to the genus *Pseudopyrina* and are differentiated on the basis of presence or absence of jaws. Jaws are present in *Pyrina* and absent in *Pseudopyrina*. No methods of differentiating their fragments, or the fragments of the species of *Pseudopyrina*, are known.

Stratigraphic occurrence.—*Pseudopyrina* occurs in the Fredericksburg and Washita groups; *P. Clarki* (Böse) in the Fort Worth and Denton formations; *P. parryi* (Hall) in the lower Washita group, and *P.* (?) *bulloides* (Cragin) in the uper Fredericksburg group.

Family Echinobrissidae Wright

This family is represented by the genus *Porobrissus* Lambert and one species *Porobrissus angustatus* (Clark) which is rare. Fragments of this genus or species, even if found, would doubtless be worthless as index fossils.

Family Ananchitidae A. Gras

This family differs greatly from any previous families discussed, but is similar in many respects to the families which follow. It is differentiated from all previous families by the fact that the ambulacra are of three types and not all identical as has been the case in previous families. The two posterior ambulacra are identical, the two antero-lateral ambulacra are

also identical, but differ from the posterior pair, and the anterior ambulacrum is totally different from the paired ambulcra. This family differs from the families which are discussed later in the matter of ornamentation, shape and size of the pores, and their arrangement, particularly in the unpaired ambulacrum.

Three genera represent this family in the Texas Cretaceous, but it has been found difficult and not entirely practical to differentiate their fragments. It has been possible, by a combination of direct and indirect means, to determine that a few fragments belong to one species which is quite common, but further than that it has not been possible to go.

Genus HOLASTER

The tubercles are small and indistinct (one or two per interambulacral plate) and usually located near the outer margin of the plate. The pore-pairs of the postero-lateral ambulacra have nearly equal, slit-like pores. The anterior pore-pairs of the antero-lateral ambulacra are rounded and smaller than the posterior pore-pairs, in the same system. The pore-pairs of the unpaired ambulacrum consist of round to circumflex pores, which are inclined to the horizontal increasingly toward the ambitus.

HOLASTER SIMPLEX Shumard

Plate 20, figures, 14–19

Holaster simplex CLARK and TWITCHELL, *1915*, U. S. Geol. Survey, Mon. 54, p. 85, pl. 34, fig. 3; pl. 38, fig. 1 (See for complete synonomy up to 1915); LAMBERT, *1927*, Bull. Soc. Géol. France, vol. 26, fasc. 3–5, p. 269; ADKINS, *1928*, Univ. Texas, Bull. 2838, p. 285, pl. 14, figs. 1, 3.

Because of the common occurrence of this species and the fact that it occurs in certain zones of abundance, it has been possible to secure fragments which undoubtedly belong to it. Whether or not these fragments can be differentiated from other species of this genus, or even other genera of this family, is not certain, since there are no fragments available for such comparison and complete specimens of all the species were not studied.

The complete test.—The test is oblong and cordiform, with an elevated, rounded upper surface, and grooved anterior margin. The lower surface is flat. The apex is nearly central, peristome transversely oval and near the anterior margin. The periproct is large and located slightly below the middle of the truncated posterior face. In a well preserved specimen the periproct is oval and on its lower end rounded, pointed toward the apex.

Ambulacral plates.—Three types of ambulacral plates exist. The plates from the postero-lateral ambulacra contain two slit-like pores very near the outer margin of the plate, and very close to the lower edge of the plate. The pores of the pair are very nearly equal in size. No tubercles occur on the plate, but numerous microscopic granules cover its surface. Plates from the antero-lateral ambulacra are identical, except that the pores decrease in size toward the anterior and even the pores of a pair differ slightly in size. Plates from the unpaired ambulacrum are distinct, and contain one pore-pair, consisting

of round to circumflex pores, inclined so that the axes form about a 45 degree angle with the horizontal. Approximate size of ambulacral plates from the ambitus: height 0.7 mm. width 5 mm.

Interambulacral plates.—These plates are considerably larger than ambulacral plates, and contain one to two tubercles (usually one) per plate. The tubercles are very small and indistinct to the naked eye, and are somewhere near the outer margin of the plate. Microscopic granules cover the surface of the plates, and give them a rough or "swarthy" appearance. This feature is peculiar to this genus.

Tubercles and granules.—The tubercles are extremely small, but very sharp in detail when examined under the microscope. This is a feature shown on nearly all fragments, but is very poorly shown on most complete specimens. No other genus of this or succeeding families has such small, but perfectly developed, tubercles. The boss of the tubercle is receding, except around its crenulate margin, where it is quite prominent. The mamelon is relatively elongate and distinctly perforate. The microscopic granules are extremely abundant, giving the whole surface of the test a finely granulated appearance.

Stratigraphic occurrence.—Duck Creek and Forth Worth formations. *Holaster comanchesi* Marcou occurs in the Duck Creek formation, and *Holaster nanus* Cragin probably in the Grayson formation. (Originally described from the "Vola Bed.")

Genus PSEUDANANCHYS

Plate 21, figures 1, 2

Differs from *Holaster* in the complete form in that it has the periproct inframarginal instead of on the posterior face. This genus is figured in Clark as having more tubercles than *Holaster*, and, as seen on figure illustrating the genus, having somewhat ovoid pores, the inner pore only one-third as large as the outer pore. All ambulacra similar.

Stratigraphic occurrence.—*Pseudananchys completus* (Cragin) occurs in the upper Washita group, and *P. supernus* (Cragin) in the Grayson formation.

Genus ECHINOCORYS

The complete form differs from *Holaster* and *Pseudananchys* in lacking the anterior groove. No characteristics for determining fragments have been determined.

Stratigraphic occurrence.—*Echinocorys texanus* (Cragin) occurs in the Anacacho formation, and *E.* cf. *texanus* (Cragin) in the Taylor.

Family PROSPATANGIDAE Lambert

The Prospatangidae differ from the Ananchitidae in that the ambulacra occupy grooves, the ambulacral pores are longer slits, the surface of the plates is roughly granular with abundant scattered tubercles and granules, and the pore-pairs of the anterior ambulacrum are different in size and shape, alternating in either a regular or irregular manner. The smaller pore-pairs of the unpaired ambulacrum have a granule

between the pores. This family differs from the Brissidae in that it has shallower ambulacral grooves, except the anterior one which is deeper than in the Brissidae. The pore-pairs of the anterior ambulacrum in the Brissidae are similar. In the Brissidae the more anterior pore-pairs of the two paired ambulacra do not decrease so greatly in size as is the case in the Prospatangidae.

The arrangement of the pore-pairs of the anterior ambulacrum in this family is quite unusual, and a fragment from this system can be recognized readily and its generic affinities determined.

Genus HETERASTER d'Orbigny
(ENALLASTER d'Orbigny 1853)

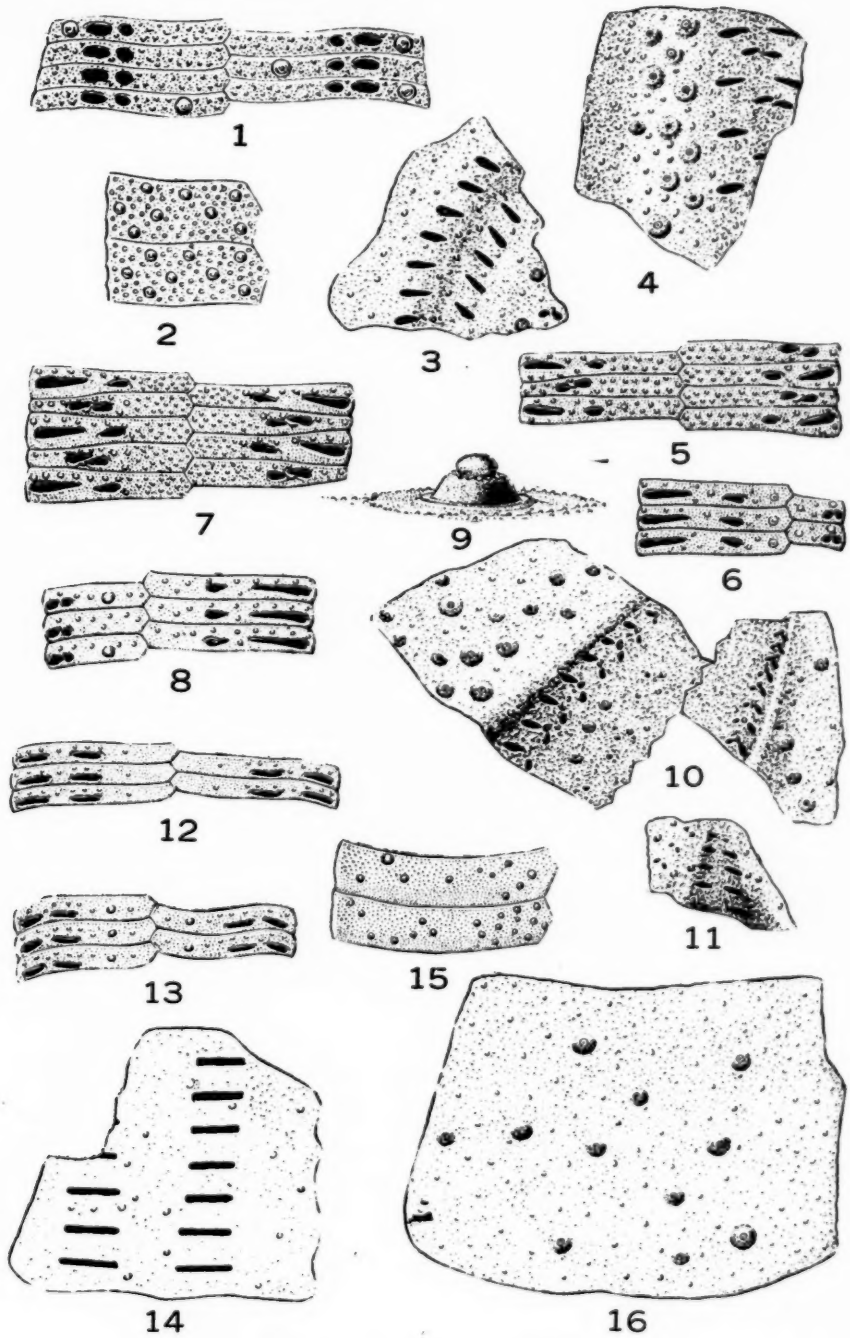
This genus contains numerous species which are very difficult to separate even in complete form. Undoubtedly many new species described and figured are merely varieties. The need for a thorough reworking of this genus is acute. The writer plans to make a thorough study of this group, with the object of making specific determinations easier. Very little can be done with the fragments at the present time.

Fragments from the unpaired ambulacrum of *Heteraster* can be distinguished from fragments of the same region from *Washitaster* because of the irregular alternation of long and short pore-pairs in the former genus. In *Washitaster* the pore-pairs are similar, but are distinctly separated by a tubercle. The tubercles of the interambulacral plates are much more numerous on the *Washitasters* than on the *Heterasters*.

One species of this genus is de-

EXPLANATION OF PLATE 21

FIGS. 1—*Genus Pseudoananchys*, ambulacral plates, figure from Clark, Texas Geol. Survey, figured specimen B (as *Holaster simplex*). ×10.
2—Interambulacral plates of same, figure from Clark, Texas Geol. Survey, figured specimen B (as *Holaster simplex*). ×5.
3—*Heteraster texanus* (Roemer), fragment from upper portion of right anterolateral ambulacrum, original (Main Street formation). ×8.5.
4—Fragment from anterior ambulacrum of same, original (Main Street formation). ×8.5.
5—Plates from anterior ambulacrum of same, figure from Clark, U. S. Nat. Mus. 9857. ×10.
6—Plates from right anterolateral ambulacrum of same, figure from Clark, U. S. Nat. Mus. 9857. ×10.
7—*Heteraster obliquatus* (Clark), plates from anterior ambulacrum, figure from Clark, U. S. Nat. Mus. 12237, type. ×10.
8—Plates from left anterolateral ambulacrum of same, figure from Clark, U. S. Nat. Mus. 12237, type. ×8.
9—Tubercle of same, figure from Clark, U. S. Nat. Mus. 12237, type. ×10.
10—*Washitaster longisulcus* (Adkins and Winton), portion of anterior ambulacrum, original (Fort Worth formation). ×8.5.
11—Portion of left anterolateral ambulacrum of same, original (Fort Worth formation). ×8.5.
12—*Macraster elegans?* (Shumard), plates from left anterolateral ambulacrum, figure from Clark, U. S. Nat. Mus. 21887. ×5.
13—Plates from anterior ambulacrum of same, figure from Clark, U. S. Nat. Mus. 21887. ×3.
14—Plates from a paired ambulacrum of same, original (Fort Worth formation). ×8.5.
15—Interambulacral plates of same, figure from Clark, U. S. Nat. Mus. 21887. ×3.
16—Interambulacral plates of same, original (Fort Worth formation). ×8.5.



Smiser—Cretaceous echinoids

scribed in detail, since fragments have been found which undoubtedly belong to this species. Although others are not described, figures are given which may indicate minor differences which exist.

HETERASTER TEXANUS (Roemer)

Plate 21, figures 3–6

Toxaster texanus ROEMER, *1852*, Die Kreidebildungen von Texas. p. 85, pl. 10, figs. 3*a–c*.

Heteraster texanus LAMBERT and THIÉRY, *1909–25*, Essai de nomenclature raissonnée des échinides, p. 438; LAMBERT, *1927*, Bull. Soc. Géol. France, vol. 26, fasc. 3–5, p. 270; ADKINS, *1928*, Univ. Texas, Bull. 2838, p. 289, pl. 3, fig. 1.

Enallaster texanus BÖSE, *1910*, Bol. Inst. Geol. Mex., no. 25, p. 166, pl. 40, figs. 6–10; pl. 41, figs. 2–4; pl. 42, fig. 1.

This species is one of the commonest fossils of the Texas Cretaceous, although numerous species which are commonly called *Heteraster texanus* really belong to other species.

The complete test.—The test is comparatively large and broad, not conspicuously narrowed posteriorly. The pores of the unpaired ambulacrum commonly occur in a regular 1:1 alternation. Periproct is transversely oval. The lower surface of the test is slightly inflated but depressed around the peristome.

Ambulacral plates.—There are three types of ambulacral plates of which only those from the unpaired ambulacrum are unique enough to be used in determining the species from fragments.

The plates of the postero-lateral ambulacra are slightly curved due to their location in shallow grooves. The pores are similar but become smaller toward the anterior. Plates from these two ambulacra, however, show only a slight difference in size for the pores of a pair.

Plates from the antero-lateral ambulacra show a great difference in pores, and the plates from the anterior half of the area are greatly decreased in size, and contain circular pores. Pore-pairs in plates from the posterior half of the area contain unequal pores. Both pores are slightly ovoid slits but the anterior pore is only about one-third the size of the posterior pore.

Plates from the unpaired ambulacrum contain alternately large and small pore-pairs, the alternations commonly being in the 1:1 manner. In pore-pairs of both sizes the inner pore is always the smaller. The pores are ovoid-slits.

Although all the existing descriptions of *H. texanus* do not entirely bear out this statement, it is believed that this species should only include those forms with the regular 1:1 alternation of the pore-pairs in the unpaired ambulacrum. More detailed work based on microscopic studies of the complete fossils and their types is necessary before certain characters of the unpaired ambulacrum can be referred definitely to particular species. The classification in general use at present for the genus *Heteraster* brings numerous species with irregular alternation in the unpaired ambulacrum under this species.

Interambulacral plates.—These plates are large and abundantly tubercled, with granules scattered over the surface of the plate. The tubercles are irregularly spaced, and occur four to ten per plate, depending on the

position of the plate in the complete system. The interambulacral plates are of very doubtful value, except for determining the genus.

Tubercles and granules.—The tubercles are crenulate and perforate. The boss rises abruptly from the test, and is nearly the same size at its crenulate margin as at the base. The mamelon is small, nearly half its surface occupied by the perforation. The granules are small and scattered, but not microscopic.

Stratigraphic occurrence.—Fredericksburg and Washita groups.

Numerous other species of *Heteraster* described from the Texas Cretaceous are listed below:

Heteraster obliquatus (Clark), Glen Rose formation (Plate 21, figs. 7–9).
Heteraster bohmi De Loriol, Lower Cretaceous series.
Heteraster texasus (d'Orbigny), Fredericksburg group.
Heteraster bravoensis (Böse), Fort Worth to Pawpaw formations.
Heteraster wenoensis (Adkins), Weno and Pawpaw formations.
Heteraster traski (Whitney), Upper Buda formation.
Heteraster adkinsi Lambert, Duck Creek formation.
Heteraster inflatus (Cragin), Grayson formation.

Genus WASHITASTER Lambert

Plate 21, figures 10, 11

Differs from *Heteraster* in having similar pore-pairs throughout the anterior ambulacrum. Each pore-pair is separated by a tubercle, and the pores are small, about equal in size to the smaller pores in the unpaired ambulacrum of *Heteraster*. In this respect it resembles the *Epiasters* and *Hemiasters* of the family Brissidae, but can be distinguished from them by its more distinct tubercles, greater curvature of the plates, ovoid-slit pores, and the close-set arrangement of the pore-pairs. Interambulacral plates are more conspicuously tubercled than in *Heteraster*, *Epiaster* or *Hemiaster*.

The fragments of the two species from the Cretaceous of Texas apparently show no characteristics by which they can be separated, aside from the fact that the interambulacral plates of *W. riovistae* contain more and larger tubercles than those of *W. longisulcus*, and that the pores of the unpaired ambulacrum of *W. longisulcus* seem to be larger and the plates more distinctly curved due to the deeper groove.

Washitaster longisulcus (Adkins and Winton), Upper Fort Worth formation.
Washitaster riovistae (Adkins), Weno formation.

Family BRISSIDAE

Members of this family have all the ambulacra situated in distinct grooves, so that the ambulacral plates are curved. Pore-pairs from the paired ambulacral areas are similar, but the pore-pairs of the anterior or unpaired ambulacrum are quite different, and differ in the various genera. The test is covered by small tubercles, which are most distinct on the plates from the ambitus. The petaloid character of the ambulacra can be detected even in fragments, if the fragments include several plates.

Four genera represent the family in the Cretaceous of Texas, and fragments of each can be differentiated by

the arrangement and character of the pores in the unpaired ambulacrum. Other features aid in separating the genera but the unpaired ambulacrum furnishes the most reliable means.

Genus MACRASTER Roemer

The paired ambulacra have pore-pairs similar and equal, with curved plates due to the grooved nature of the ambulacral areas. The pores are very wide slits, a pore-pair occupying two-thirds of the width of an ambulacral plate; plates not so conspicuously granuled as in other genera of the family. The pore-pairs of the unpaired ambulacrum are slits arranged en chevron and are distinctly smaller than the pores of the paired ambulacra. Plates of the interambulacra are large, and rather sparsely granuled with the granules concentrated in the plates which approach the ambulacral systems.

The species of this genus are so similar in many respects that specific determination is difficult even with complete forms. Doubtless many of the differences on which the species are based could better be explained by calling those species varieties. In the Fort Worth formation, where the genus *Macraster* is very abundant, occur countless fragments which can only be identified as *Macraster*. The bulk of these fragments are so similar as to defy any sort of separation. However, some few can questionably be assigned to certain species due to very slight differences. These differences include the curvature of ambulacral plates which show the grooved nature of the ambulacra; the amount of ornamentation, and the relative size of the plates.

MACRASTER ELEGANS (Shumard)

Plate 21, figures 12–16

Hemiaster elegans SHUMARD, *1854*, Pal. Expl. Red River of Louisiana in 1852, p. 184, pl. 2, figs. 4*a–c;* ADKINS and WINTON, *1920*, Univ. Texas, Bull. 1945, p. 53, pl. 8, figs. 3–4.

Macraster cfr. texanus BÖSE, *1910*, Bol. Inst. Geol. Mex., p. 172, pl. 47, fig. 5; pl. 48, figs. 3, 5.

Macraster elegans LAMBERT and THIÉRY, *1909–25*, Essai de nomenclature raisonnée des échinides, p. 472; LAMBERT. *1927*, Bull. Soc. Géol. France, vol. 26, fasc. 3–5, p. 272; ADKINS, *1928*, Univ. Texas, Bull. 2838, p. 295, pl. 14, fig. 4.

It is difficult to determine accurately this species even with complete specimens, and a great number of forms which are commonly called *M. elegans* are probably nearer to *M. texanus* or *M. aguilerae*. The fragments most certain to belong to this species however, are interambulacral plates which are sparsely covered by tubercles, and ambulacral plates which are curved showing the grooved character of the ambulacral systems.

Stratigraphic occurrence.—Upper Duck Creek and entire Fort Worth formations.

MACRASTER TEXANUS (Roemer)

Macraster texanus ROEMER, *1888*, *Macraster*, eine neue Spatangoiden-Gattung aus der Kreide von Texas. N. Jahrb., vol. 1, p. 191–195, pl. 26; ADKINS, *1928*, Univ. Texas, Bull. 2838, p. 295, pl. 13, figs. 4–5.

Ambulacral pores more linear; plates from ambulacra show little or no curvature; plates of interambulacra quite granular.

Stratigraphic occurrence.—Fort Worth formation.

MACRASTER WASHITAE Lambert

Macraster washitae LAMBERT, *1920*, Bull. Soc. Sci. Hist. et Nat. Yonne, p. 28; LAMBERT and THIÉRY, *1909–25*, Essai de nomenclature raisonnée des échinides, p. 472; LAMBERT, *1927*, Bull. Soc. Géol. France, vol. 26, fasc. 3–5, p. 272; ADKINS, *1928*, Univ. Texas, Bull. 2838, p. 296.

Hemiaster whitei CLARK and TWITCHELL, *1915*, U. S. Geol. Survey, Mon., 54, p. 89, pl. 45, figs. 1*a–c*.

Pores of unpaired ambulacrum transverse rather than en chevron. No fragments found could be definitely assigned to this species.

Stratigraphic occurrence.—Fort Worth? formation.

MACRASTER AGUILERAE (Böse)

Macraster aguilerae BÖSE, *1910*, Bol. Inst. Geol. Mex., no. 25, p. 173, pl. 47, figs. 2–4, 6–7; pl. 48, figs. 1–2, 4; LAMBERT and THIÉRY, *1909–25*, Essai de nomenclature raisonnée des échinides, p. 472; ADKINS, *1928*, Univ. Texas, Bull. 2838, p. 296.

Epiaster aguilerae ADKINS, *1920*, Univ. Texas, Bull. 1856, p. 109, pl. 5, fig. 5; pl. 8, fig. 7.

Little curvature in ambulacral plates; the surface minutely granuled; ambulacral plates relatively narrow as compared with *M. elegans* and *M. texanus*.

Stratigraphic occurrence—Fort Worth and Denton formations.

Other species of *Macraster* whose fragments offer few clues to identification at present, are:

Macraster nodopyga Lambert, Fort Worth? formation (Plate 22, figs. 1–2).

Macraster subobesus (Adkins), Upper Weno formation.

Macraster wenoensis (Adkins), Weno and Pawpaw formations.

Macraster sp. Lambert (*Hemiaster* species B. Adkins and Winton), Goodland and Comanche Peak formations. Considered by Lambert as a small, not yet fully developed phase of *M. elegans*.

Genus EPIASTER

The pore-pairs of the paired ambulacra are similar, much narrower than in *Macraster* and the plates are more sharply curved. The interporiferous areas are less smooth than in *Macraster*. The pores of the unpaired ambulacrum are ovoid-slits, arranged en chevron and separated by an oblong granule. Interambulacral plates are coarsely granuled.

EPIASTER WHITEI (Clark)

Plate 22, figures 3–12

Hemiaster whitei CLARK and TWITCHELL, *1915*, U. S. Geol. Survey, Mon. 54, p. 89, pl. 43, figs. 2*a–c;* pl. 45, figs. 2*a–f*, *not* 1*a–c;* LAMBERT and THIÉRY, *1909–25*, Essai de nomenclature raisonnée des échinides, p. 502.

Epiaster whitei LAMBERT, *1927*, Bull. Soc. Géol. France, vol. 26, fasc. 3–5, p. 272. ADKINS, *1928*, Univ. Texas, Bull. 2838, p. 297.

A very common species occurring in great abundance in certain formations. The pores perforating the ambulacral plates are slits, but not linear as in the *Macrasters*. The opening is large compared to the width of the pore. Pores of the unpaired ambulacrum are ovoid or round, separated by a granule and arranged en chevron, the inner pore smaller than the outer. Interambulacral plates are abundantly tubercled.

Stratigraphic occurrence.—Goodland-Duck Creek formations.

Epiaster bösei Lambert, Comanche Peak formation. No material was available for a study of this species.

Genus HEMIASTER Desor

The presence of a peripetalous fasciole, and the distinctly grooved character of the ambulacra serve to

separate this genus from its close relatives the *Epiasters*. Since fragments are unlikely to be found which would show anything of a fasciole, there is left only the curvature of the ambulacral plates to distinguish this genus from the preceding one. In the absence of other criteria therefore, it is very doubtful if the fragments of *Epiaster* and *Hemiaster* could be successfully differentiated, except where the fragments are of considerable size and show some of the characters of the complete fossil. Species from the Texas Cretaceous, of which fragments of two are figured here, are:

Hemiaster calvini Clark, Buda, Main Street and Grayson formations (Plate 22, figs. 13–17).

Hemiaster bexari Clark, Washita group (Plate 22, fig. 18).

Hemiaster comanchei Clark, Glen Rose formation.

Hemiaster texanus Roemer, Austin formation.

Hemiaster americanus Giebel, Austin formation.

Genus Proraster Lambert

The ambulacral pores are ovoid, with distinctly curved plates. The tubercles of the interambulacral plates are scrobiculate. No fragmentary material has been studied.

Proraster dalli (Clark), Washita group (Plate 22, fig. 19).

SUMMARY AND CONCLUSIONS

Echinoids are important fossils in the Cretaceous rocks of Texas, especially in those of the Comanchean

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Explanation of Plate 22

Figs. 1—*Macraster nodopyga* Lambert, plates from anterior ambulacrum, figure from Clark, Texas Geol. Survey (as *Hemiaster elegans*). ×5.

2—Interambulacral plates of same, figure from Clark, Texas Geol. Survey (as *Hemiaster elegans*). ×5.

3–4–5—*Epiaster whitei* (Clark), fragments from anterior ambulacrum, original (Goodland formation). ×8.5.

6—Two plates from height in a paired ambulacrum of same, original (Fort Worth formation). ×8.5.

7—Plates from low in left anterolateral ambulacrum of same, figure from Clark, U. S. Nat. Mus. 9732, type (as *Hemiaster whitei*). ×8.

8—Plates from low in right anterolateral ambulacrum of same, original (Goodland formation). ×8.5.

9—Plates from a posterolateral ambulacrum of same, original (Fort Worth formation). ×8.5.

10—Interambulacral fragment of same, original (Goodland formation). ×8.5.

11—Interambulacral plates of same, figure from Clark, U. S. Nat. Mus. 9732, type (as *Hemiaster whitei*) ×3.

12—Spine of same, original (Goodland formation). ×15.

13—*Hemiaster calvini* Clark, interambulacral fragment, original (Grayson formation). ×8.5.

14—Interambulacral plate of same, figure from Clark, U. S. Nat. Mus. 12241, type. ×3.

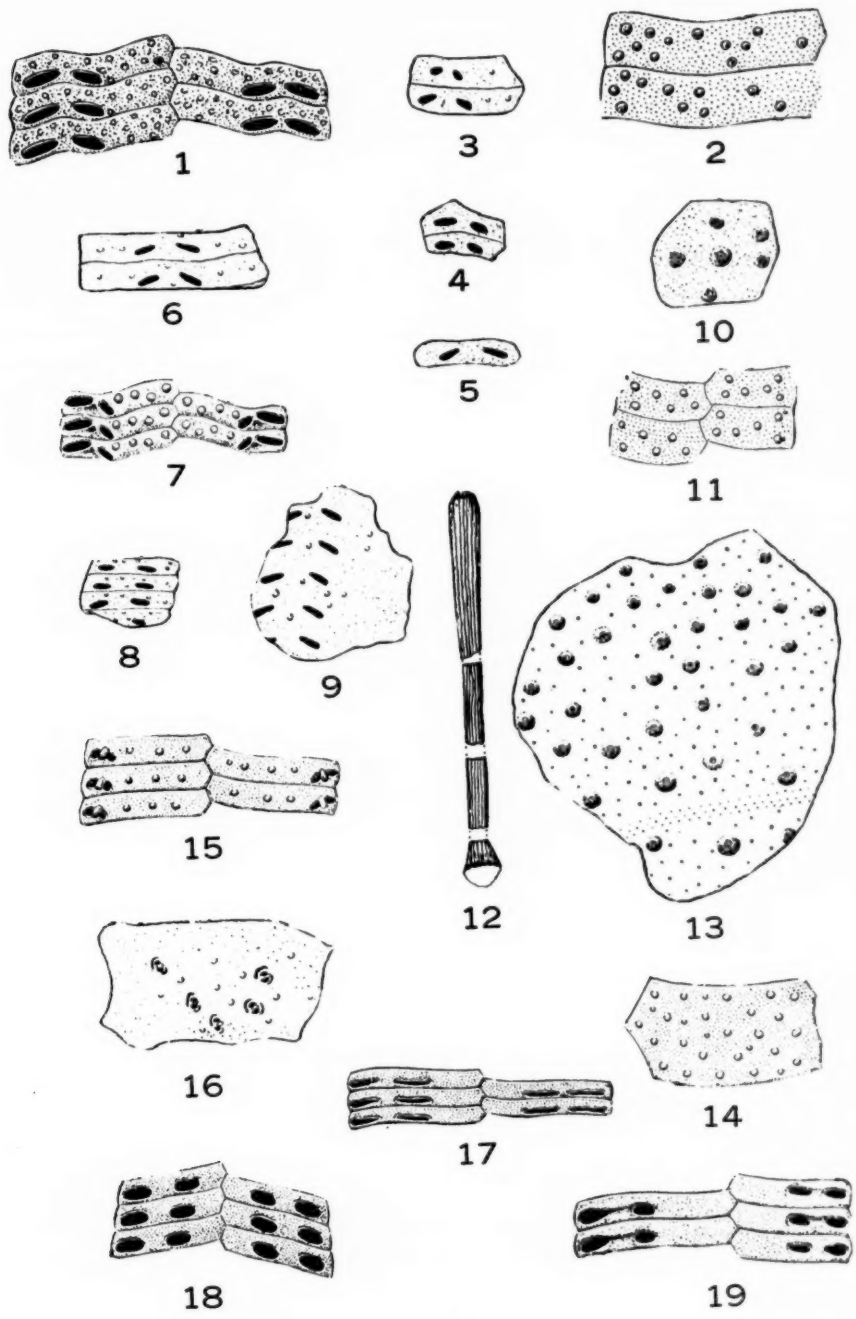
15—Plates from anterior ambulacrum of same, figures from Clark, U. S. Nat. Mus. 12241. Type. ×5.

16—Fragment from lower end of anterior ambulacrum of same, original (Grayson formation). ×8.5.

17—Plates from paired ambulacra of same, figure from Clark, U. S. Nat. Mus. 12241, type. ×5.

18—*Hemiaster bexari* Clark, plates from paired ambulacra, figure from Clark, U. S. Nat. Mus. 8330, type. ×5.

19—*Proraster dalli* (Clark), plates from paired ambulacra, figure from Clark, U. S. Nat. Mus 18114, type (as *Hemiaster dalli*). ×5.



Smiser—Cretaceous echinoids

or Lower Cretaceous series. Many species have been described, and many of them have proved to be useful index fossils.

Each of the units of the echinoid test usually carries some characteristic feature of a family, a genus, or even a species. Although entire tests are not rare, the greater proportion of the fossilized remains of echinoids occur as scattered plates. Their common occurrence, and the possibility that they might be used as index fossils, indicated that a detailed study of these fragments would yield interesting results. This paper is a contribution to such a detailed study. In order that the fragments might be used as index fossils, means of identifying them as specifically as possible have been developed. The problem was attacked by examining with the microscope many entire tests, and fragments that were known to belong to certain families, genera and species, and by studying all the detailed figures and descriptions available in the literature. The results of this study have demonstrated that all the families, nearly all the genera, and numerous species, can be identified from fragments alone, and that these fragments can, therefore, be used as index fossils.

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LOWER MIOCENE FORAMINIFERA FROM THE SOUTHERN SAN JOAQUIN VALLEY, CALIFORNIA

W. F. BARBAT AND F. E. VON ESTORFF

ABSTRACT

This paper describes 19 species and varieties (6 new) of Lower Miocene foraminifera from the Vaqueros formation of the southern San Joaquin Valley of California.

A new Lower Miocene foraminiferal fauna has been found in beds equivalent to the Vaqueros formation in the southern part of the San Joaquin Valley. The recognition of the Vaqueros age of this fauna is of considerable importance because there has been no previous record of Vaqueros foraminifera in the literature.

These Lower Miocene foraminifera were secured from a road cut on the east side of a small canyon draining northward into Cienega syncline, and located 2,000 feet south and 1,350 feet east of the NW. cor. of sec. 10, T. 11 N., R. 22 W., S.B. B.L. & M.; 7½ miles southeast of Maricopa, Kern County, California, (California Academy of Science Loc. 27,278). The foraminifera occur in a clay bed, 3 to 6 inches thick, within the lower portion of a massive sandstone series mapped as Vaqueros by R. W. Pack.[1]

The Vaqueros formation, described by H. Hamlin in 1904[2], is the lowest known marine Miocene formation in California and is characterized by the *Turitella inezana* fauna. The Vaqueros formation is normally overlain by the Temblor formation,[3] or its shaly equivalents which are included in the Salinas Shale[4] and the Maricopa Shale.[5]

In the area southeast of Maricopa the beds mapped as Vaqueros formation are overlain by the Maricopa shale. The lower 1,200 feet of the Maricopa shale correspond to the Temblor formation, and the upper 3,200 feet to 7,800 feet correlate with the Monterey formation as it is exposed at the town of Monterey, California. The Vaqueros formation is underlain by the San Lorenzo formation of Oligocene age. The stratigraphic sequence in the vicinity of

[1] Pack, Robert W., The Sunset-Midway oil field, California: *U. S. Geol. Survey, Prof. Paper* 116, 1920.

[2] Hamlin, H., *U. S. Geol. Survey, Water-Supply Paper* 89, p. 14, 1904.

[3] Described by Anderson, F. M., *Calif. Acad. Sci., Proc.*, (3), vol. 2, pp. 168–187, 1905.

[4] Described by English, W. A., *U. S. Geol. Survey, Bull.* 691, pp. 219–250, 1918.

[5] Described by Pack, *Op. cit.*

California Academy of Science Loc. 27,278 is as follows:

		Thickness in feet
Maricopa shale	Monterey shale...	3,600
	Temblor shale....	1,200
Vaqueros formation. Massive sandstone with minor beds of black clay shale.....		5,000
San Lorenzo. Massive dark brownish-gray shale with thin lenses of fossiliferous, calcaerous sandstone.....		2,000

The lower portion of the Maricopa shale is exposed in Cienega syncline near the SW. cor. of section 33, T. 11 N., R. 23 W. At this location the following distinctive Temblor foraminifera species were collected:

Bolivina advena Cushman
Bolivina advena var. ornata Cushman
Bolivina floridana Cushman
Bolivina marginata Cushman
Bulimina cf. inflata Seguenza
Buliminella subfusiformis Cushman
Cibicides floridanus (Cushman)
Dentalina pauperata d'Orbigny
Dentalina quadrilata Cushman and Laiming
Gyroidina soldanii d'Orbigny
Nodosaria parexilis Cushman and K. C. Stewart.
Planulina sp.
Plectofrondicularia miocenica Cushman
Pulvinulinella subperuviana var. *minuta* Cushman and Laiming
Robulus americanus (Cushman)
Virgulina californiensis Cushman

Additional Temblor species were found at the same horizon two miles east.

Glandulina laevigata d'Orbigny
Globobulimina pacifica Cushman
Nodosaria anomala Reuss
Plectofrondicularia californica Cushman
Sphaeroidina cf. variabilis Reuss

Standard Oil Company of California locations	S.O. Loc. 443	S.O. Loc. 444	S.O. Loc. 445	S.O. Loc. 446	S.O. Loc. 447	S.O. Loc. 448
Antigona mathewsoni (Gabb)	x	x	x	x		
Bruclarkia gravida (Gabb)	x	x				x
Calyptraea sp.		x				
Dentalium cf. *stentor* Anderson & Hanna			x	x		
Dentalium sp.	x	x				
Epitonium sp.		x				
Glycimeris cf. *tenuimbricata* Clark				x		
Metis rostellata Clark	x	x	x	x	x	x
Mulinia? sp.	x	x				
Natica recluziana Petit	x	x				
Pecten columbianus Clark & Arnold				x		
Pitaria lorenzana Clark				x		
Siphonalia merriami Wagner & Schilling		?				x
Thyasira folgeri Wagner & Schilling		x				

The San Lorenzo Beds, underlying the Vaqueros formation, are moderately fossiliferous. A check list of San Lorenzo fossils found underlying California Academy of Science Loc. 27,278 is given in the table on page 165.

Standard Oil Company of California locality descriptions:

443: Santiago Creek. 2,000 feet east and 1,900 feet south of the NW. cor. sec. 14, T. 10 N., R. 23 W., S.B.B.L. & M.

444: Santiago Creek. 800 feet west and 400 feet north of S.O. Loc. 443.

445: Santiago Creek. 3,100 feet west and 3,000 feet south of the NE. cor. sec. 15, T. 10 N., R 23 W., S.B.B.L. & M.

446: Santiago Creek. 500 feet west of S.O. Loc. 445.

447: Santiago Creek. 1,500 feet east and 400 feet north of S.O. Loc 445.

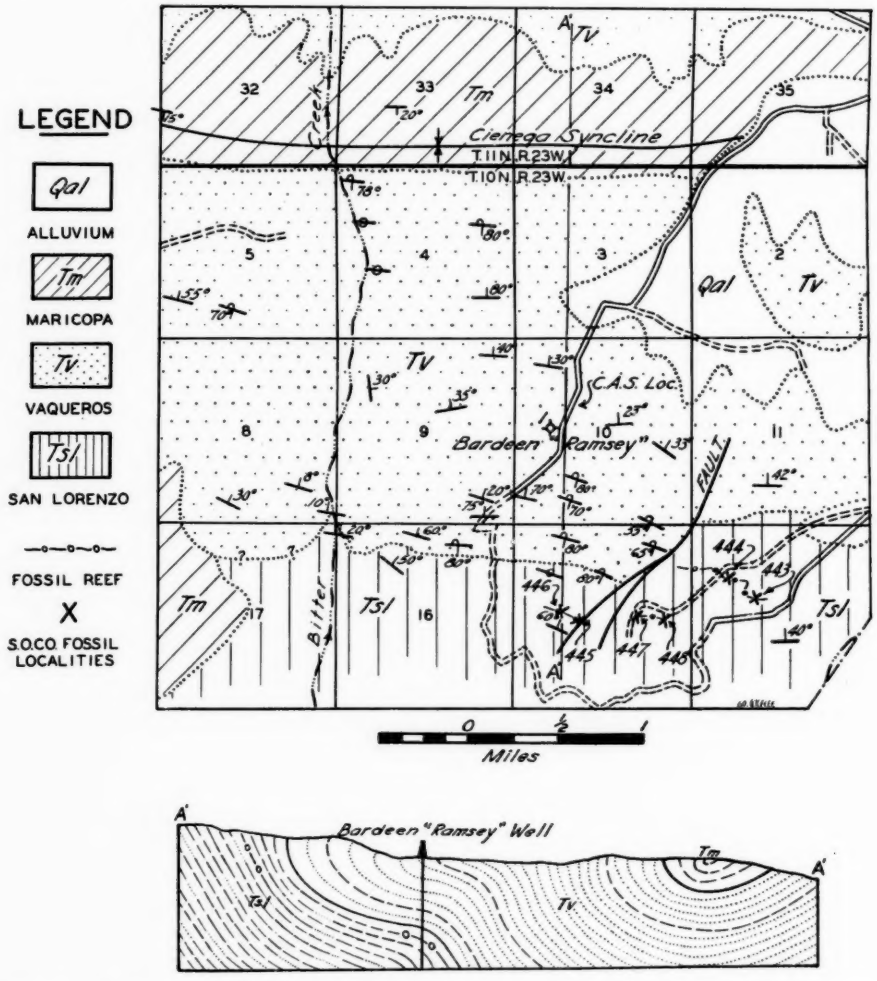


FIG. 1. Sketch map and geologic cross-section showing location of California Academy of Science Loc. 27,278 and other fossil localities. Geology after Robt. W. Pack, *U. S. Geol. Survey, Prof. Paper* 116, in part.

448: Santiago Creek. 2,300 feet east and 200 feet north of S.O. Loc. 445.

The San Lorenzo fauna listed above is equivalent to the upper Pleito fauna of the San Lorenzo beds in the San Emigdio region.[6] B. L. Clark has pointed out the faunal break between the upper Pleito fauna and the underlying San Lorenzo faunal zones of the lower Pleito and San Emigdio formations.[7] A brief study of this upper Pleito fauna shows that it is unquestionably younger than the "*Molopophorus lincolnensis*" zone of the Oligocene and that it is approximately equivalent to the so-called "*Acila gettysburgensis*" or "*Agasoma gravida*" upper Oligocene zones. The upper Pleito fauna occupies the position commonly regarded as uppermost Oligocene.

No determinable molluscan fossils have been found associated with the foraminiferal shale in the Vaqueros sandstone. Toward the east the Vaqueros sandstones become fossiliferous and, in the San Emigdio foothills, Loel and Corey[8] list the following: *Glycimeris branneri*, *Ostrea vaquerosensis*, *Modiolus ynezianus*, *Thais carrizoensis*, and *Scutella vaquerosensis*. East of San Emigdio, lower members of the Vaqueros grade into continental deposits. In the area of Tecuya Creek the continental members, known as the Tecuya formation, have yielded remains of land mammals which have been identified by Chester Stock[9] as related to the lower Miocene and upper Oligocene faunas found elsewhere in North America.

Toward the west and northwest of Maricopa the Vaqueros extends, as a semi-continuous band of sandstone, overlying Oligocene dark shales and underlying fossiliferous Temblor beds into the Salinas Valley and the type locality of the Vaqueros formation.

VAQUEROS FORAMINIFERA

The Vaqueros foraminiferal fauna described in this paper contains nineteen species of which only five or six species[10] are common to horizons lower than Miocene. Eleven species or varieties range into the Temblor formation, and four species are present in horizons higher than Temblor. Six species and varieties at this time are believed to be characteristic of the Vaqueros.

Species related to the Vaqueros forms appear to be more abundantly represented in the Temblor formation than in any other known horizon. Several Vaqueros species are closely related to Temblor species. *Uvigerina gesteri* n. sp. is obviously a progenitor

[6] Wagner, C. M., and Schilling, K. H., The San Lorenzo group of the San Emigdio region, California: *Calif. Univ., Dept. Geol. Sci. Bull.*, vol. 14, no. 6, pp. 245–246, 1923.

[7] Hoots, H. W., Geology and oil resources along the southern border of the San Joaquin Valley, California: *U. S. Geol. Survey, Bull.* 812-D, p. 254, 1930.

[8] Loel, Wayne, and Corey, W. H., The Vaqueros formation, Lower Miocene, of California: *Calif. Univ., Dept. Geol. Sci. Bull.*, vol. 22, no. 3, 1932.

[9] Stock, Chester, An early Tertiary vertebrate fauna from the southern Coast Ranges of California: *Calif. Univ. Dept. Geol. Sci., Bull.*, vol. 12, no. 4, 1920.

[10] Although the micro-fauna of the Eocene is fairly well known at the present time, the Oligocene micro-fauna remains imperfectly known. Foraminifera collected by H. G. Schenck from the upper beds of the type San Lorenzo in Kings and Bear creeks have been available to the authors.

of Temblor siphogenerinas of the *Siphogenerina raphanus* (Parker and Jones) type and of a related undescribed *Uvigerina* known only from the lower Temblor of Carneros Creek.

The relations of the Vaqueros fauna to Kreyenhagen and Wagonwheel faunas of Upper Eocene and probably lowermost Oligocene age respectively are less close.

SUMMARY

The evidence derived from the study of this fauna shows conclusively that it is of Miocene age. The stratigraphic evidence indicates that it is from the lower part of the Vaqueros formation and therefore from the earliest Miocene beds known in California.

DESCRIPTION OF SPECIES

Family LITUOLIDAE

Subfamily HAPLOPHRAGMINAE

Genus HAPLOPHRAGMOIDES Cushman, 1910

HAPLOPHRAGMOIDES ADVENA Cushman (?)

Plate 23, figure 20

Haplophragmoides advena CUSHMAN, *1925*, Contr. Cushman Lab. Foram. Research, vol. 1, p. 38, pl. 6, figs. 1*a*, 1*b*.

The specimens in this fauna are rather poor in that they show no details. The aperture is unknown. The number of chambers in the last coil varies from 10 to 11. The figured specimen has the following dimensions: Length, 0.86 mm.; breadth, 0.68 mm.

Lower Miocene, Kern County, California.

Family LAGENIDAE

Subfamily NODOSARIINAE

Genus ROBULUS Montford, 1808

ROBULUS POLITUS (Schwager)

Plate 23, figures 17*a*, *b*

Cristellaria polita SCHWAGER, *1866*, Novara Exped., Geol. Theil, pt. 2, p. 243, pl. 6, fig. 87.

Only imperfect specimens were obtained. Schwager's figures are somewhat conventionalized, and the species is probably quite variable.

Lower Miocene, Kern County, California.

ROBULUS NIKOBARENSIS (SCHWAGER) var. WARMANI Barbat and von Estorff, n. var.

Plate 23, figures 12*a*, *b*

Test planispiral, bilaterally symmetrical, close coiled, periphery angular, keeled, eight chambers visible in the last formed coil; wall calcareous, finely perforate; sutures distinct, limbate, curved, becoming broader at the margin; sutures become confluent forming an irregular ring about the umbilical area which is covered with clear shell material; aperture radiate, with the proximal slit enlarged, in an apertural chamberlet at the top of the last formed chamber. Diameter, 0.56 mm.; breadth, 0.16 mm.

Holotype of variety (California Academy of Science No. 5,767) from beds mapped as Vaqueros, Southern San Joaquin Valley (California Academy of Science Loc. 27,278).

This distinctive form is placed, for the present, as a variety of *R. nikobarensis* (Schwager) because of its re-

semblance to that variable species. Variety *warmani* differs from *R. nikobarensis* chiefly in the angulated periphery, a character not found in immature specimens. The variety is named in honor of Thomas Warman Koch, who was one of the collectors, and who assisted the writers with information on the general geology of the region.

Genus DENTALINA d'Orbigny, 1826

DENTALINA QUADRULATA Cushman and Laiming

Plate 23, figures 1, 3, 4

Dentalina quadrulata CUSHMAN and LAIMING, *1931*, Contr. Cushman Lab. Foram. Research, vol. 7, part 1, p. 3, pl. 1, figs. 9–11.

Incomplete individuals of this characteristically ribbed *Dentalina* are present. In the early stages this material conforms with Cushman and Laiming's species from the Temblor formation. More complete material may ultimately show that considerable variation occurs in the adult stage, the Temblor representatives of the species showing decreased number and strength of costae.

Lower Miocene, Kern County, California.

DENTALINA (?) sp.

Material too fragmentary for identification is present in the Vaqueros collection.

Genus NODOSARIA Lamarck, 1812

NODOSARIA LONGISCATA d'Orbigny

Fragments apparently belonging to this species are present. The species was originally described from the Miocene of the Vienna Basin. It is close to *N. arundinea* Schwager which has been recorded from Eocene to Pliocene.

NODOSARIA ANOMALA Reuss (?)

Nodosaria anomala REUSS, CUSHMAN and PARKER, *1931*, Contr. Cushman Lab. Foram. Research, vol. 7, pt. 1, p. 4, pl. 1, figs. 12–14.

Only immature specimens with the earliest chambers are present; they may compare with *Nodosaria anomala* Reuss as figured by Cushman and Parker from the Temblor formation.

NODOSARIA KOINA Schwager

Plate 23, figure 8

Although slightly different from the original species, it is referred to *N. koina* as described by Cushman and other authors from California Miocene formations.

Lower Miocene, Kern County, California.

NODOSARIA (?) sp.

Plate 23, figure 15

The figured specimen, consisting of the later chambers only, is considered worthy of record in this material until complete specimens allow full identification.

Lower Miocene, Kern County, California.

Genus SARACENARIA Defrance, 1824

SARACENARIA ITALICA Defrance (?)

Plate 23, figure 16

Only immature forms questionably referred to *Saracenaria italica* Defrance are present in the Vaqueros collection. They may prove to be distinct from Defrance's species.

Lower Miocene, Kern County, California.

Family HETEROHELICIDAE

Genus PLECTOFRONDICULARIA Liebus, 1903

PLECTOFRONDICULARIA n. sp.

Plate 23, figure 5

Test small, much compressed, broadly elliptical in front view; initial end rounded, slightly inflated; chambers distinct, early ones coiled about the proloculum, then biserial, and later extending back towards the initial end on either side; sutures distinct, slightly limbate, with a very slight depression in the curve in the later portion which is more marked on opposite sides in succeeding chambers; wall smooth except for a single, short, raised costa on the inflated portion of the initial end.

The figured specimen, from the Lower Miocene, Vaqueros horizon, of Kern County, is obviously a megalospheric form. It is related to *P. vaughani* Cushman, originally described from the Alazan clay (Upper Eocene) in Mexico, and reported from the Miocene of Venezuela and California. The material is too incomplete for the description of a new species. It is, however, believed to be characteristic of the Vaqueros horizon. Material identical to the figured specimen has been found in the Vaqueros of Monterey County, California.

EXPLANATION OF PLATE 23

FIGS. 1, 3, 4—*Dentalina quadrulata* Cushman and Laiming. Plesiotypes, Nos. 5768, 5769, 5770, C. A. S. Coll. ×72.5.

2—*Nodogenerina advena* Cushman and Laiming (?), Plesiotype, No. 5782, C. A. S. Coll. ×55.

5—*Plectofrondicularia* sp. plesiotype, No. 5772, C. A. S. Coll. ×72.5.

6*a*, 6*b*—*Gyroidina soldanii* d'Orbigny. ×90.

7, 18—*Uvigerina gesteri* Barbat and von Estorff, n. sp. 7, Megalospheric form, Holotype, No. 5773, C. A. S. Coll. 18, Microscopic form, Paratype, No. 5774, C. A. S. Coll. ×65.

8—*Nodosaria koina* Schwager. Plesiotype, No. 5781, C. A. S. Coll. ×75.

9*a*, *b*—*Buliminella subfusiformis* Cushman. Plesiotype, No. 5777, C. A. S. Coll. ×65.

10*a*, *b*—*Uvigerinella obesa* Cushman var. *impolita* Cushman and Laiming. Plesiotype, No. 5771, C. A. S. Coll. ×80.

11*a*, *b*—*Pullenia octoloba* Barbat and von Estorff, n. sp. Holotype, No. 5779, C. A. S. Coll.-×90

12*a*, *b*—*Robulus nikobarensis* (Schwager) var. *warmani* Barbat and von Estorff, n. var. Holotype of variety, No. 5767, C. A. S. Coll. ×65.

13*a*, *b*, *c*—*Uvigerina kernensis* Barbat and von Estorff, n. sp. *b*, Mature specimen with spines eroded, paratype, No. 5775, C. A. S. Coll. ×65. *c*, Holotype, No. 5776, C. A. S. Coll. ×75.

14*a*, *b*—*Bolivina marginata* Cushman. Plesiotype No. 5778, C. A. S. Coll. ×65.

15—*Nodosaria* (?) sp. (?) ×65.

16—*Saracenaria italica* Defrance (?). Plesiotype, No. 5780, C. A. S. Coll. ×55.

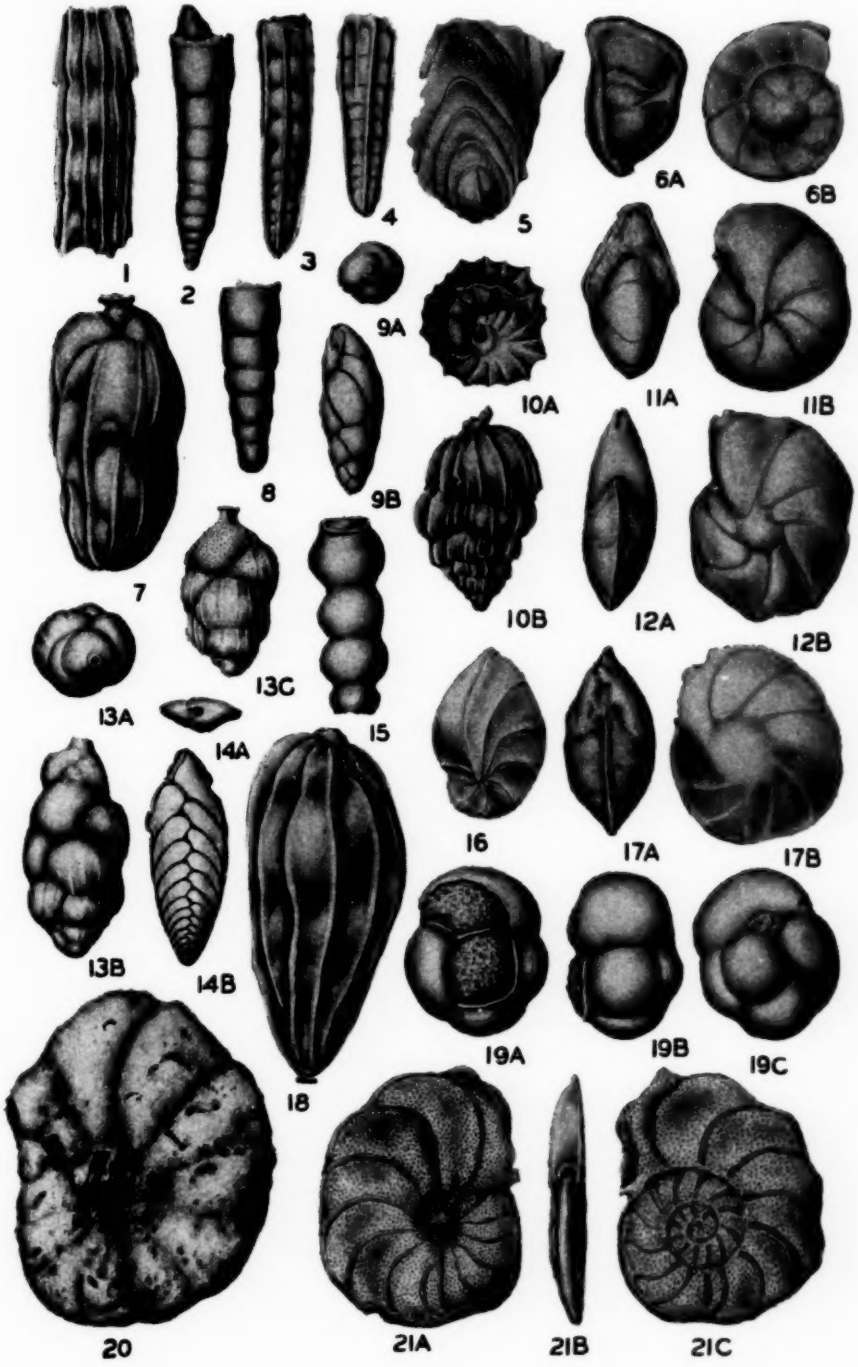
17*a*, *b*—*Robulus politus* (Schwager). Plesiotype, No. 5766, C. A. S. Coll. ×65.

19*a*, *b*, *c*—*Sphaeroidina variabilis* Reuss. Plesiotype, No. 5783, C. A. S. Coll. ×65.

20—*Haplophragmoides advena* Cushman. Plesiotype, No. 5765, C. A. S. Coll. ×72.5.

21*a*, *b*, *c*—*Cibicides floridanus* Cushman, var. *cushmani* Barbat and von Estorff, n. var. Holotype of variety, No. 5784, C. A. S. Coll. ×90.

All of the specimens illustrated on this plate are from California Academy of Science Loc. 27,278; Vaqueros formation, Kern County, California.



Barbat and Von Estorff, Miocene Foraminifera

Family HETEROHELICIDAE

Subfamily EOUVIGERINAE

Genus NODOGENERINA Cushman, 1927

NODOGENERINA ADVENA Cushman and Laiming?

Plate 23, figure 2

This species, described from the Miocene of Los Sauces Creek, Ventura County, is abundantly represented in the Temblor formation of the San Joaquin Valley. Incomplete specimens which probably belong to the same species are present in the Vaqueros collection.

Lower Miocene, Kern County, California.

Family BULIMINIDAE

Subfamily TURRILININAE

Genus BULIMINELLA Cushman, 1911

BULIMINELLA SUBFUSIFORMIS Cushman

Plate 23, figures 9*a*, *b*

Buliminella subfusiformis CUSHMAN, *1925*, Contr. Cushman Lab. Foram. Research, vol. 1, part 2, p. 33, pl. 5, fig. 12. CUSHMAN and PARKER, *1931*, Contr. Cushman Lab. Foram. Res., vol. 7, part 1, p. 8, pl. 1, fig. 29.

The species is common in the California Miocene. It occurs frequently in the collection from the Vaqueros horizon in Kern County.

Genus BOLIVINA d'Orbigny, 1839

BOLIVINA MARGINATA Cushman

Plate 23, figures 14*a*, *b*

Bolivina marginata CUSHMAN, *1918*, U. S. Geol. Survey, Bull. 676, p. 48, pl. 10, fig. 1; *1925*, Contr. Cushman Lab. Foram. Research, vol. 1, p. 30, pl. 5, figs. 5*a*, *b*.

The specimens in this collection are smaller and more fusiform in outline than those from the Monterey and Temblor formations, but evidently belong to the same species.

Lower Miocene, Kern County, California.

Subfamily UVIGERININAE

Genus UVIGERINELLA Cushman, 1926

UVIGERINELLA OBESA Cushman, var. IMPOLITA Cushman and Laiming

Plate 23, figures 10*a*, *b*

Uvigerinella obesa CUSHMAN, var. *impolita* CUSHMAN and LAIMING, *1931*, Jour. Paleontology, vol. 5, no. 2, p. 111, pl. 12, figs. 11*a*, *b*.

Test small, short, broad; broadest toward the apertural end, initial end bluntly tapering, periphery lobulate; sutures depressed; walls ornamented with prominent, plate-like, longitudinal costae, those of each chamber independent of adjacent ones; costae tending to be angulated at the base of each chamber; aperture terminal, elliptical, twisted, with a short neck and lip. Length 0.48 mm., breadth 0.31 mm.

The variety has been described from the Miocene of Los Sauces Creek, Ventura County, California.

Lower Miocene, Kern County, California.

UVIGERINA GESTERI Barbat and von Estorff, n. sp.

Plate 23, figures 7, 18

Test rather short and bluntly terminated at the initial end in the megalospheric form, more elongate and tapering in the microspheric form; chambers numerous, inflated; sutures obscured by ornamentation; walls ornamented with 10 to 12 prominent, lamellate, longitudinal costae which usually extend from the initial end to the base of the apertural neck; costae independent of the chambers except in the megalospheric form with cos-

tae frequently becoming obsolete on the last formed chamber and several costae not confluent on adjacent chambers; aperture terminal, with a short cylindrical neck and phialine lip. Length 1.00 mm.; maximum breadth of megalospheric form, 0.40 mm.; of microspheric form, 0.54 mm.

Holotype (California Academy of Science No. 5,773) from beds mapped as Vaqueros, southern San Joaquin Valley (California Academy of Science Loc. 27,278).

The species is closely related to *U. gallowayi* Cushman described from the Miocene of Venezuela. It differs from that form in the following respects: *U. gallowayi* has a greater number of costae, a stronger tendency of the costae to be interrupted at the sutures, and to become obsolete on the last formed chambers. Another closely related species occurs near the base of the Temblor (Miocene) formation at its type locality on Carneros Creek.

It is named in honor of Mr. G. C. Gester, Chief Geologist of the Standard Oil Company of California, and one of the pioneer geological workers of the southern San Joaquin Valley. He was the first to recognize in the San Emigdio Hills, beds of Oligocene age which are separable from Eocene below and Miocene above.

Genus UVIGERINA d'Orbigny, 1826

UVIGERINA KERNENSIS Barbat and von Estorff n. sp.

Plate 23, figures 13*a*, *b*, *c*

Test triserial, fusiform, greatest width near middle; periphery lobulate, chambers distinct, numerous; wall calcareous, with about 18 to 20 moderately raised longitudinal costae in complete circumference, becoming lower and less conspicuous on later chambers; last two or three chambers in adult usually without costae, but ornamented with minute spines; costae nearly confluent on adjacent chambers; aperture terminal, rounded, with a short cylindrical neck and phialine lip. Length 0.60 mm., breadth 0.31 mm.

Holotype of species (figure 13*c*) (California Academy of Science No. 5,776), Paratype of more mature but slightly eroded form (California Academy of Science No. 5,775), from beds mapped as Vaqueros, southern San Joaquin Valley, California (California Academy of Science Loc. 27,278).

The species compares with *U. cocoaensis* Cushman, but can be distinguished from that form in having a slightly more lobulate periphery, by 18 to 20 costae, and by a greater number of chambers as well as the tendency to be slightly spinose on the last formed chambers. In this latter respect it approaches *U. pigmea* d'Orbigny from which it differs in fewer and less conspicuous costae, and a shorter neck. The costae of *U. pigmea* occur on all but the last one or two chambers, whereas adult forms of *U. kernensis* have several chambers without costae. The spines of *U. pigmea* d'Orbigny are more conspicuous.

U. cocoaensis was described from the upper Eocene of Alabama.[11] *U.*

[11] Cushman, J. A., *Contr. Cushman Lab. Foram. Research*, vol. 1, part 3, p. 68, pl. 10, fig. 12, 1925.

pigmea was originally described by d'Orbigny[12] from the Pliocene of Italy. He later referred to his species, specimens from the Miocene of the Vienna Basin, but, according to Cushman[13] these two do not seem to be identical.

Family ROTALIIDAE

Subfamily DISCORBISIDAE

Genus GYROIDINA d'Orbigny, 1826

GYROIDINA SOLDANII d'Orbigny

Plate 26, figures 6*a*, *b*

Cushman[14] states: "This widely distributed species is abundant in Ecuador, Venezuela and Trinidad as well as in the Miocene of the Coastal Plain of the United States and in the earlier Tertiary of many regions as well as Recent." D'Orbigny's type is from the Miocene of the Vienna Basin.

Lower Miocene, Kern County, California.

Family CHILOSTOMELLIDAE

Subfamily ALLOMORPHINELLINAE

Genus PULLENIA Parker and Jones, 1862

PULLENIA OCTOLOBA Barbat and von Estorff, n. sp.

Plate 23, figures 11*a*, *b*

Test planispiral, close coiled, bilaterally symmetrical, biconvex; periphery lobulate, rounded; chambers distinct, eight in the last coil; wall calcareous, smooth, finely perforate; sutures depressed, distinct, slightly curved; umbilicus overgrown by the last formed chambers; aperture narrow, crescent shaped, at the base of the last formed chamber. Diameter 0.43 mm.; thickness 0.28 mm.

Holotype (California Academy of Science No. 5,779) from beds mapped as Vaqueros, southern San Joaquin Valley, California (California Academy of Science Loc. 27,278).

The species resembles *Pullenia multilobata* Chapman, but the latter is more evenly rounded. The number of chambers, eight instead of five or six, distinguishes it from *P. quinqueloba* Reuss, and *P. salisburyi* Stewart and Stewart.

Subfamily SPHAEROIDININAE

Genus SPAEROIDINA d'Orbigny, 1826

SPHAEROIDINA VARIABILIS Reuss

Plate 23, figures 19*a*, *b*, *c*

Spaeroidina variabilis REUSS, *1851*, Zeitschr. deutsch, geol. Ges., vol. 3, p. 88, pl. 7, figs. 61–64; CUSHMAN, *1929*, Contr. Cushman Lab. Foram. Res., vol. 5, p. 101, pl. 14, figs. 15*a–c*.

This variable species is abundant in the Oligocene and Miocene of many European localities.

Lower Miocene, Kern County, California.

Family ANOMALINIDAE

Subfamily ANOMALININAE

Genus CIBICIDES Montford, 1808

CIBICIDES FLORIDANUS (Cushman), var. CUSHMANI Barbat and von Estorff, n. var.

Plate 23, figures 21*a*, *b*, *c*

Test very much compressed in the adult, with the chambers quickly evolute and widely spreading, the earlier chambers being visible from both sides of the test; 12 or 13 chambers in the last formed coil; periph-

[12] d'Orbigny, *Annales Sci. Nat.*, vol. 7, p. 269, pl. 12, figs. 8, 9, 1826.

[13] Cushman, J. A., *Contr. Cushman Lab. Foram. Research*, vol. 6, part 3, p. 63, 1930.

[14] Cushman, J. A., *Contr. Cushman Lab. Foram. Research*, vol. 5, p. 98, 1929.

ery lobulate, bluntly keeled; sutures distinct, limbate, confluent with keel; wall calcareous, coarsely perforate; aperture an arched slit at the base of the last formed chamber. Diameter 0.46 mm., thickness 0.09 mm.

Holotype (California Academy of Science No. 5,784) from the Vaqueros, southern San Joaquin Valley, California (California Academy of Science Loc. 27,278).

The figured specimen is believed to be the megalospheric form; the microspheric form was not recognized. The new variety can be distinguished by lack of superimposed ornamentation in the umbonate region, and in that the earliest chambers are not obscured on the dorsal side. It is named in honor of Dr. J. A. Cushman whose assistance in the preparation of the present paper is much appreciated.

JOURNAL OF PALEONTOLOGY, VOL. 7, NO. 2, PP. 175–177, PL. 24, JUNE, 1933

TWO SPECIES OF MIOGYPSINA FROM THE OLIGOCENE OF MEXICO[1]

W. L. F. NUTTALL
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ABSTRACT

Two species of *Miogypsina* are described from the Oligocene of Tampico embayment of Mexico. They are *M. mexicana* n. sp. and *M. complanata* Schlumberger.

INTRODUCTION

This paper presents for the first time description of species of *Miogypsina* from Mexico. Two forms are herein described, each having restricted stratigraphical range in the Oligocene.

Miogypsina mexicana n. sp. occurs in beds considered to be Lower Oligocene in age and is found associated with a microforaminiferal fauna bearing many Alazan species. *M. complanata* Schlumberger is a peculiar coiled form, which is restricted to the Middle Oligocene Meson formation and occurs near the type locality at Meson in the State of Veracruz. The presence of *Miogypsina* in Mexico was recently recorded by H. E. Thalmann.[2]

DESCRIPTION OF SPECIES

MIOGYPSINA MEXICANA Nuttall n. sp.
Plate 24, figures 1–6, 8, 10, 12

Description. Test equilateral, biconvex, circular or roundly oval in shape. Greatest thickness near the center. In megaspheric forms the average diameter is 1.6 to 2 mm. and average thickness 0.7 mm. Surface tuberculate, the average diameter of the tubercles being 0.1 mm. Microspheric forms, which are rare, attain a maximum diameter of 5 mm. and have the initial part of the test protruding.

The nucleoconch consists of two somewhat unequal chambers, separated by a straight or nearly straight septum. The average length across the two chambers is 0.3 to 0.4 mm., the average width being 0.2 mm. One chamber is subspherical and the other approaches a hemispherical shape. The primordial chambers are immediately surrounded by about twelve subequal oval chambers. The later chambers are diamond-shaped, their average length measured radially being 0.15 mm. and average width 0.1 mm. The nucleoconch is excentric, being situated from 0.4 to

[1] Published by permission of the Mexican Eagle Oil Company.

[2] Thalmann, H. E., *Eclog. Geol. Helvet.*, vol. 25, p. 282, 1932.

0.5 mm. away from the periphery, with its longer axis either parallel or at right angles to the longer axis of the median chambers. The height of the median chambers is 0.5 to 0.7 mm., the lateral wall being from 0.3 to 0.4 mm. thick. There are about five or six lateral chambers superimposed irregularly one upon the other.

Remarks. This species may be distinguished from *M. hawkinsi* Hodson[3] by the latter having more unequal chambers in the nucleoconch and fewer initial spiral chambers. It is quite distinct from the other seven species so far described from America.[4]

MIOGYPSINA COMPLANATA Schlumberger

Plate 24, figures 7, 9, 11, 13, 14

Miogypsina complanata SCHLUMBERGER, *1900*, Bull. Soc. Géol. France sér. 3, vol. 28, p. 330, pl. 2, figs. 13–16; pl. 3, figs. 18–21. SILVESTRI, *1930*, Boll. Soc. Geol. Ital., vol. 48, p. 210, figured in vol. 42, pl. 1, fig. 19.

[3] Hodson, F., *Bull. Amer. Paleontology*, vol. 12, no. 47, p. 28, 1926.

[4] Vaughan, T. W., *Jour. Paleontology*, vol. 1, p. 284, 1927. Barker, R. W., *Geol. Mag.*, vol. 69, p. 277, 1932.

Description. Test discoidal, average diameter 1.3 mm., maximum observed diameter 1.9 mm. In some specimens the length and width are equal, while in others one or the other may be the greater. Surface covered with numerous papillae of variable shape and size, their diameter varying from 0.2 to 0.1 mm., tubercles of this last size being the most frequent. In young specimens the coiling of the earlier chambers may sometimes be seen externally, also towards the periphery in adults the chambers of the median layer are sometimes visible. The average thickness of the test is 0.5 mm.

An equatorial section shows a single initial chamber of diameter varying from 0.05 to 0.18 mm. This is surrounded by 1½ to two coiled chambers, about 15 to 25 in number, followed by numerous lozenge shaped chambers. In transverse section the height of the chambers is from 0.2 to 0.3 mm.

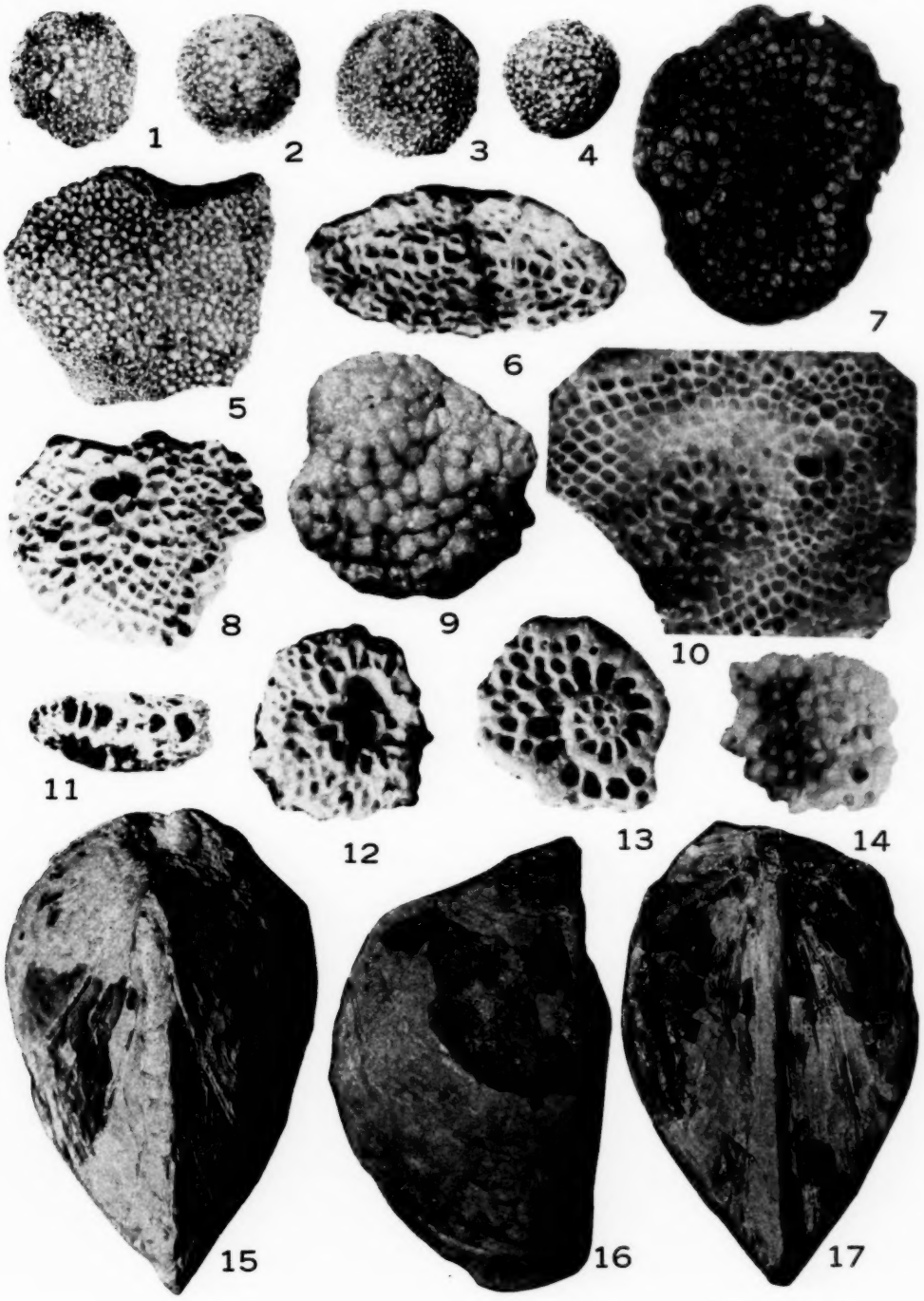
Remarks. This is the first descrip-

EXPLANATION OF PLATE 24

FIGS. 1–6, 8, 10, 12—*Miogypsina mexicana* Nuttall n. sp. Papantla-Tajin Road, bend in road NE. of Finca de los Tremari, State of Veracruz. 1–4, Megalospheric specimens, ×10; 5, Microspheric specimens, ×10; 6, Transverse section by reflected light, ×25; 8, 10, 12, Equatorial sections by reflected light, ×25.

7, 9, 11, 13, 14—*Miogypsina complanata* Schlumberger, ×25. Equatorial section by transmitted light. 800 metres E. of La Laja Blanca, Hacienda Asuncion, State of Veracruz; 9, Empire San José de las Rusias well 2, 130 feet; 11, Transverse section by reflected light. Arroyo Huizotate, at junction of Rio Totolapa, Hacienda Mecatepec, State of Veracruz; 13, Equatorial section by reflected light, same locality as fig. 9; 14. 1,100 metres NNE. of Meson, State of Veracruz.

15–17—*Lophonychia cordata* Stewart, n. sp.; 15, Postero-hinge view of a cotype showing the short hinge. 16, View of the right valve of a cotype showing the terminal position of the beak, the vertical profile of the anterior end, and the rounded form of the posterior margin. 17, Anterior view of the specimen shown in Fig. 16 illustrating the heart-shaped outline of the shell as seen from the anterior. The outside margin marks the sharp umbonal ridges of the valves.



Nuttall, Oligocene Foraminifera
Stewart, Devonian Pelecypod

tion of a coiled type of *Miogypsina* from America. The form appears to be identical with this species described from the Miocene (Aquitanian) of France, which was also recorded by Silvestri as rare in the Oligocene of Italy.

In Mexico this species is found in typical Meson formation associated with *Lepidocyclina gigas* Cushman and *Lepidocyclina undosa* Cushman, which beds are regarded by Vaughan and Cole as of Middle Oligocene age.[5]

The figured specimens and paratypes have been deposited in Doctor Cushman's collection.

[5] Vaughan, T. W., *Geol. Soc. America, Bull.*, vol. 35, p. 732, and table 3. 1924. Cole, W. S., and Gillespie R., *Bull. Amer. Paleontology*, vol. 15, no. 57*b*, p. 4, 1930.

JOURNAL OF PALEONTOLOGY, VOL. 7, NO. 2, PP. 178–180, JUNE, 1933

A NEW PELECYPOD FROM THE SILICA SHALE, DEVONIAN, OF OHIO

GRACE ANNE STEWART
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ABSTRACT

This paper describes a new pelecypod from the Silica shale, the genus of which has not been recognized previously in the Devonian rocks of Ohio.

INTRODUCTION

During the past year a few specimens belonging to a new species of the recently described genus *Lophonychia* have been collected from the Silica shale, Lucas County, Ohio. Some of the specimens were collected by the writer, and some were given by Mr. C. D. Miller, of Sylvania. Mr. Miller has on several previous occasions generously contributed to the collections of the Department of Geology at Ohio State University, and we wish to acknowledge once again our great appreciation of his generosity and continued interest in the work.

The genus *Lophonychia* was established by Pohl[1] in 1929 to include two species, *Lophonychia cultellata* Pohl and *Lophonychia trigonale* (Cleland). The latter, which was selected as the genotype, was previously described as *Mytilarca trigonale.* Pohl's description of the genus is as follows:

"Shell equivalve, sharply convex, obliquely triangular ovate; with a short hinge, scarcely alate posteriorly, but with a definite hinge plate; beaks terminal, incurved, acute, and extending considerably beyond the cardinal line; antero-umbonal slope abrupt, high, vertical; byssal opening small or none. Hinge with small cardinal and lateral teeth, longitudinally excavated for a linear ligament. The position of the posterior adductor scar is, in specimens preserving it, one of the most pronounced distinguishing features of the shell. It is situated on the post-basal margin of the shell, above the simple pallial line nearly as far down as possible, is large and only slightly indented on its dorsal edge. The pallial line is very sharply marked in casts of the interior."

This is the first time that the genus *Lophonychia* has been recognized in the Devonian rocks of Ohio.

[1] Pohl, E. R., *Milwaukee Public Mus., Bull.*, vol. 11, no. 1, p. 48, 1929.

DESCRIPTION

Family AMBONYCHIDAE

Genus LOPHONYCHIA Pohl

LOPHONYCHIA CORDATA Stewart, n. sp.

Plate 24, figures 15–17

Shell of medium size, the dimensions of an average specimen being length 37 mm., height 50 mm., thickness 25 mm. A smaller specimen and one of slightly different proportions measures length 30 mm., height 45 mm., thickness 27 mm. Shell outline viewed laterally, broadly triangular—ovate to elongate semicircular; valves equal, thick, the thickest part occurring on the dorsal anterior third. Hinge line straight, approximately equal to the greatest length of the shell, extending posteriorly and probably resulting in a small cardinal ear, although this feature can not be determined with certainty from the specimens studied. Beaks small, acute, rising only a short distance above the hinge line and only slightly incurved.

Anterior abruptly truncate, descending vertically from the beaks and producing an acute umbonal ridge in the anterior-umbonal regions of the valves; anterior view of shell heart-shaped in outline. Posterior to the umbonal ridge the shell surface slopes uniformly and more or less abruptly to the margins. The posterior margin is evenly rounded and curves gradually into the short basal margin. Byssal opening not evident.

Surface markings are fine concentric striations, which are crowded at intervals where growth was temporarily checked. On the anterior end the abrupt truncation of the shell makes the lines run vertical. They continue across the umbonal ridge to the posterior slope where they terminate obliquely at the margin and along the hinge. A small hinge plate is present, but the teeth which are assumed to be present can not be recognized from the specimens studied. The shell substance is extremely thin so that the fine growth lines of the exterior surface are usually quite noticeably impressed on casts of the interior.

Pohl lists as a distinguishing feature of the genus the position of the posterior adductor muscle scar near the post-basal margin of the shell. Of the several specimens examined, all of them casts of the interior, no recognizable muscle imprints occur except on one specimen, where a slightly impressed ovate indentation is present near the post-basal margin of the right valve just above the pallial line.

The outstanding characters of *L. cordata* are the extremely inequilateral valves, the abrupt truncation of the antero-lateral portion of the shell, and the carinated antero-umbonal slopes.

Silica shale, Devonian, Lucas County, Ohio.

Discussion.—This interesting species is represented in our collections by less than a dozen specimens, all of them casts of the interior, but two or three of them have retained some portions of the shell. The slight distortion of some of the shells along the hinge

suggests a weak hinge structure. No two specimens examined are exactly identical, yet there are no obvious differences which would serve as a plausible basis for separation into different species.

This species is quite distinct from the two species of the genus previously described by Pohl. From *Lophonychia trigonale* it differs in the larger size, the absence of a sulcus on the antero-lateral slope, and it is relatively longer dorsally. From *Lophonychia cultellata* it differs in being larger, in having a longer hinge line, and the shell is more decidedly triangular in outline.

Two specimens belonging to the genus *Lophonychia* from the Long Lake series of Michigan were kindly loaned to me for inspection by Professor G. M. Ehlers. These are comparable to the Silica shale species here described but the shape is somewhat different and they may represent a distinct species.

Cotypes.—No. 17565 (3 specimens) Geol. Mus. Ohio State Univ.

JOURNAL OF PALEONTOLOGY, VOL. 7, NO. 2, PP. 181–214, PLS. 25–27, JUNE, 1933

SHELL STRUCTURE OF THE OSTRACODE GENUS CYTHEROPTERON, AND FOSSIL SPECIES FROM THE CRETACEOUS OF TEXAS

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ABSTRACT

The criteria commonly employed by paleontologists in the classification of fossil Ostracoda are discussed. The finer structures of the shells of Ostracoda are described in detail, and the systematic significance of these features indicated. The diagnostic shell characters of the genus *Cytheropteron*, as revealed by the genotype, *C. latissimum* (Norman), are described. The genus is subdivided into two subgenera, and a number of characteristic species of each are described from the Cretaceous of Texas. Two new genera are erected to receive some species which have been erroneously referred to *Cytheropteron*, and the correct generic assignment is indicated for others.

INTRODUCTION

One of the most difficult problems encountered by students of the Cretaceous and Tertiary Ostracoda is that of making correct generic assignments of their fossil species. The principal difficulty lies in the fact that most of the genera to which Cretaceous and Tertiary ostracode species are referred, were originally described by zoologists and not by paleontologists. Classification of the Recent Ostracoda is based principally upon the characters of the appendages, and zoologists, while describing these structures with great care, have as a rule given but meager and unsatisfactory accounts of the structure of the carapace-valves. In the case of the fossil specimens, this shell is all that remains, and it is on the basis of its structures that the paleontologist must make his generic determinations.

Jones and Hinde[1] in the introduction to their "Supplementary Monograph of the Cretaceous Entomostraca of England and Ireland" expressed the belief that the character of the shell is "so closely correlated with other structural features of the organism, that it may very reasonably be considered as affording a safe clue to their systematic relationships." Other paleontologists have shared this view, but unfortunately many of them have based their generic assignments upon purely superficial similarities in appearance, and have overlooked the truly fundamental and significant features of shell structure.

The features most commonly employed by paleontologists in distin-

[1] Jones, T. R., and Hinde, G. J., A supplementary monograph of the Cretaceous Entomostraca of England and Ireland: *Paleont. Soc. London*, p. iv, Introduction, 1890.

guishing the genera of Cretaceous and Tertiary Ostracoda are the general shape and form of the shell, the general type of surface marking or sculpturing, and in members of the family Cytheridae, the nature and arrangement of the hinge teeth at the dorsal or articular edge of the valves. Of these, the hinge structure is the most reliable guide, as the character and arrangement of the hinge teeth is remarkably constant within each generic group. The other characters named are also useful and are sufficiently reliable when critically and judiciously employed. Much confusion and disagreement in the classification of the fossil Ostracoda has resulted, however, from careless use of these criteria. The most conspicuous features of shell shape are frequently the least reliable in making generic assignments. For example, many paleontologists have referred all species characterized by the presence of wing-like lateral expansions of the shell at the ventral margin to the genus *Cytheropteron*. Several genera of the family Cytheridae have winged species, however, and these structures are, therefore, of little value in making generic assignments. The proper generic relationship of any alate species is indicated by other features of shell shape, as well as by other shell structures. Certain features of shell shape are constant for each genus, while others are highly variable. A study of several species of a genus will quickly indicate to the critical observer which features of shell form or outline are constant for the genus in question.

G. W. Müller was the first student of Ostracoda to study and describe in detail the finer structures of the shell, and to suggest the systematic significance of these characters. The following description of these features is modified for application to fossil specimens, from his monograph[2] on the Ostracoda of the Gulf of Naples.

The shell of Ostracoda consists of two layers, known as the outer and inner lamellae. The two lamellae are very different in structure. The outer (O, pl. 25, figs. 5*a*, 6), is thicker than the inner, and is entirely calcified. The inner (I) consists of two portions, a peripheral, calcified portion (Ic) and a thin, membranous central portion (Im). The central portion is never preserved in fossils. The boundary between the two portions, or in other words, the inner edge of the calcified portion of the inner lamella is known as the inner margin (B). The outer edge of the shell is known as the outer margin (M).

The peripheral, calcified portion of the inner lamella is indistinguishably fused with the outer lamella for a part or the whole of its width, and the line along which the two unite is known as the line of concrescence (L). The narrow area around the margins of the shell between the line of concrescence and the outer margin is known as the marginal zone.

The line of concrescence usually runs near and parallel to the outer margin of the shell. Its distance from

[2] Müller, G. W., Die Flora und Fauna des Golfes von Neapel, Monogr. 21, Ostracoda, 1894.

the outer margin, and its course are features of great taxonomic significance.

The course of the inner margin is likewise a feature of importance. In some genera, it coincides throughout with the line of concrescence (pl. 25, figs. 5*a*, *b*). In others it is at a greater or lesser distance within this line, along a part of the whole of its length. In most of the latter genera the inner margin approaches or coincides with the line of concrescence between the middle and the anterior third of the ventral margin (pl. 25, fig. 2), and in some the two coincide along the entire ventral margin. In these genera the course of the inner margin may be regular, following the curvature of the outer margin of the shell, or may be very irregular and complicated.

The shell of Ostracoda is pierced by numerous canals, which open on both the exterior and interior surfaces of the shell, and are known as pore-canals. These canals bear hair-like bristles during the life of the animal. There are two types of pore-canals; first, those which pierce the marginal zone of the shell, opening internally along the line of concrescence, and externally on or near the outer margin of the shell, and known as the radial canals (R), and those which are disposed at right angles to the surface of the shell, known as the normal canals (N, pl. 25, figs. 5*a*, 6).

The radial pore-canals strongly influence the appearance of the shell, especially in those genera in which the marginal zone is broad and transparent. In some the canals are few in number, in others, numerous; in some they are narrow, in others wide, in some simple, in others branched. In many genera the canals exhibit a bulbous enlargement near the middle or between the middle and the outer margin (pl. 25, figs. 5*a*, *b*). In some genera they open internally by a wide, funnel-shaped opening (pl. 25, fig. 2), in others by a small pore (pl. 25, figs. 5, 6). The number, arrangement and structure of the radial pore-canals are features of taxonomic importance.

The clear observation of the pore-canals and also of the line of concrescence and inner margin is usually greatly facilitated by mounting a single valve in Canada balsam, and examining it by transmitted light. It is often impossible to determine the exact course of the inner margin in fossil Ostracoda, since the inner lamella is usually fragile and easily broken. But even in specimens in which this structure is partially destroyed, and the course of the inner margin therefore altered, it is important to observe, if possible, the approximate distance by which the inner margin and the line of concrescence are separated.

Lienenklaus,[3] in his studies of the German Tertiary Ostracoda, was the first paleontologist to apply these criteria in the generic allocation of fossil species, and was also the first to suggest that the arrangement of the small pits or scars made by the retractor muscles on the interior sur-

[3] Lienenklaus, E., Die tertiär-Ostrakoden des mittleren Nord-deutschlands: *Zeits. deutsch. geol. Gesell.*, vol. 53, p. 500, 1900.

face of the valves[4] is also a feature of taxonomic significance. Lienenklaus states that the muscle scar pattern can be used in differentiating family groups only, but the observations of the present writer indicate that this character may in some cases be of value in making generic distinctions and assignments. Unfortunately the muscle scars are not always discernible in fossil specimens. These scars, like the other finer shell structures, may sometimes be observed by mounting a single valve in Canada balsam on a glass slide, and viewing by transmitted light. Individuals in which the finer shell structures cannot be observed still may be correctly assigned, however, on the basis of the shell characters discussed above: namely, general shape of shell, general type of surface sculpture, and hinge structure.

The only way in which the paleontologist can hope to achieve a correct classification for the fossil Ostracoda is to make a careful and detailed study of the shell structure of the type species of all Cretaceous, Terti-

[4] Lienenklaus, E., Monographie der Ostrakoden des nordwest-deutschen Tertiärs: *Zeits. deutsch. geol. Gesell.*, vol. 46, p. 166, 1894.

EXPLANATION OF PLATE 25

FIGS. 1*a*, *b*, *c*—*Orthonotacythere hannai* (Israelsky). *a*, Anterior marginal zone and pore-canals; *b*, posterior marginal zone and pore-canals; *c*, muscle scar pattern, interior of right valve; *a* and *b*, ×80; *c*, ×160.

2—Valve of a typical ostracode viewed by transmitted light (Symbols as in Fig. 6).

3*a*, *b*, *c*—*Brachycythere sphenoides* (Reuss). *a*, Anterior marginal zone and pore-canals; *b*, posterior marginal zone and pore-canals; *c*, muscle scar pattern, interior of right valve; *a* and *b*, ×80; *c*, ×160.

4—*Cytheropteron* (*Cytheropteron*) *navarroense* Alexander; muscle scar pattern, interior of right valve, ×160.

5*a*, *b*—*a*, Diagrammatic section through the margin of an ostracode shell in which the inner margin and line of concrescence coincide. *b*, Anterior end of same specimen as seen by transmitted light. (Symbols as in Fig. 6).

6—Diagrammatic section through the margin of an ostracode shell (modified from G. W. Müller). *O*—outer lamella, *I*—inner lamella, *Im*—membraneous central portion of inner lamella, *Ic*—calcified peripheral portion of inner lamella, *B*—inner margin, *L*—line of concrescence, *R*—radial pore canals, *N*—normal canals.

7—*Cytheropteron* (*Cytheropteron*) *wenoense* Alexander; dorsal view, outline, ×35.

8—*Cytheropteron* (*Eocytheropteron*) *paenorbiculatum* Alexander, n. sp; dorsal view, outline, ×35.

9—*Brachycythere ledaforma* (Israelsky); dorsal view, outline. ×35.

10—*Cytheropteron* (*Cytheropteron*) *rugosalatum* Alexander; dorsal view, outline; ×35.

11—*Cytheropteron* (*Eocytheropteron*) *bilobatum* Alexander; dorsal view. ×35.

12—*Cytheropteron* (*Eocytheropteron*) *delrioense* Alexander, n. sp.; dorsal view, outline, ×35.

13*a*, *b*—*Cytheropteron* (*Cytheropteron*) *latissimum* (Norman). *a*, Anterior marginal zone and pore-canals; *b*, posterior marginal zone and pore canals; ×80.

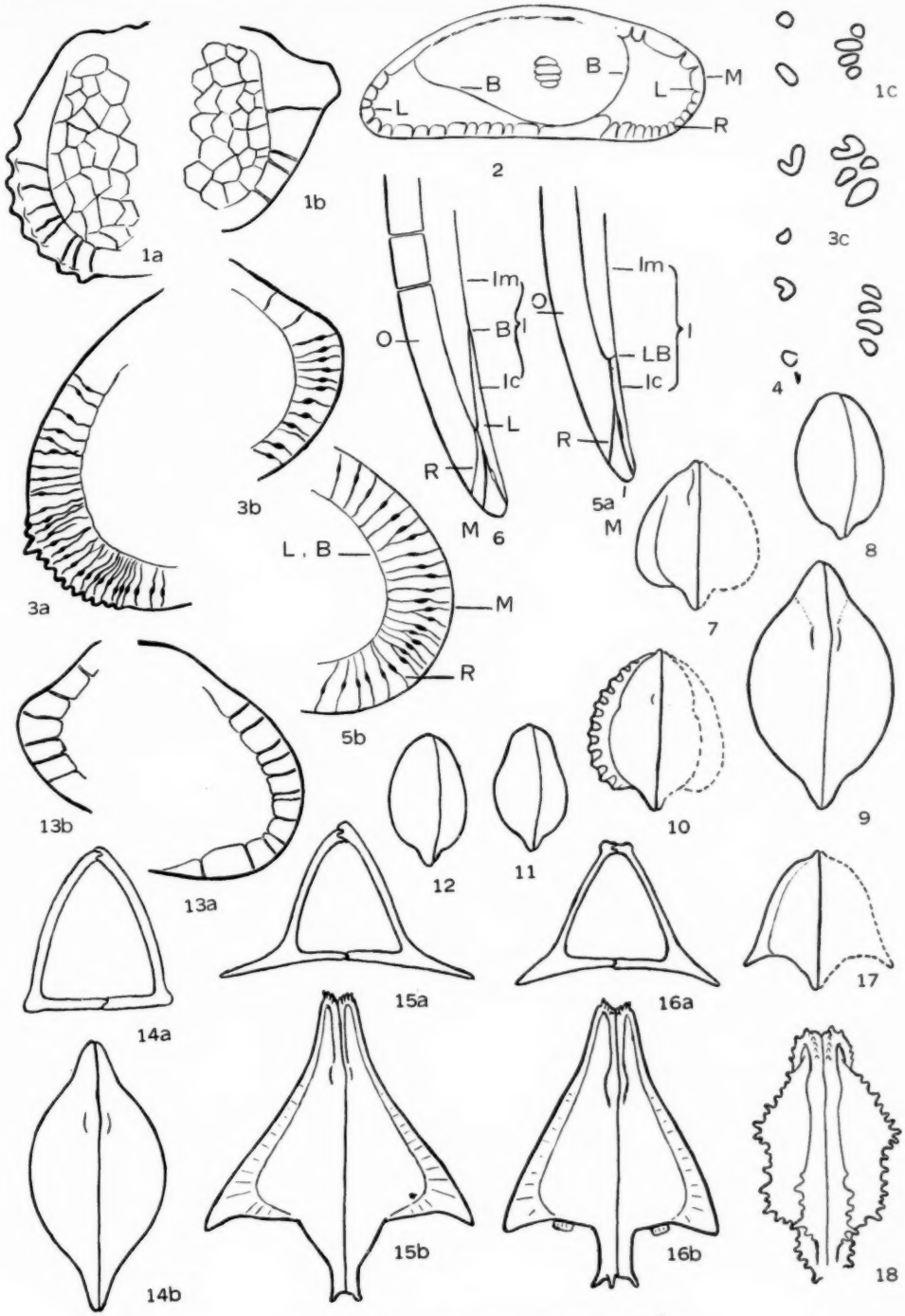
14*a*, *b*—*Brachycythere sphenoides* (Reuss). *a*, Transverse section, to show triangular form; *b*, dorsal view, outline; ×35.

15*a*, *b*—*Brachycythere alata* (Bosquet). *a*, Transverse section to show triangular form; *b*, dorsal view, outline; ×35.

16*a*, *b*—*Cythereis thomasi* Israelsky. *a*, Transverse section to show quadrate form; *b*, dorsal view, outline; ×35.

17—*Cytheropteron* (*Cytheropteron*) *bicornutum* Alexander, n. sp.; dorsal view, outline; ×35.

18—*Cythereis ornatissima* (Reuss); dorsal view, outline; ×35.



Alexander—Cretaceous ostracodes

ary and Recent ostracode genera. Even those genera having fossil species as genotypes have been, on the whole, inadequately described. Every important feature of shell structure should be described in the minutest detail possible. If the paleontological classification of the Ostracoda falls short of perfection, the fault is with the student, not with the Ostracoda. The various genera are characterized by distinctive features of shell structure. The paleontologist, in seeking to discover these distinguishing characters, must take into consideration more features, and must study these in greater detail than in the past.

The genus *Cytheropteron* Sars, 1865, has been, perhaps, the least understood of all the genera to which Cretaceous and Tertiary Ostracoda are referred. All of the species described by various authors under this name are certainly not congeneric, and many species of *Cytheropteron*, have been erroneously referred to the genus *Cytheridea*, on account of a strong superficial resemblance between the hinge structures of the two genera.

It is the purpose of the present paper to describe as completely and accurately as possible the shell structure of the genus *Cytheropteron*, as revealed by the type species; to describe a number of characteristic species of *Cytheropteron* from the Cretaceous of Texas; and to indicate correct generic assignments for some of the species which have been erroneously referred to this genus.

It has been found possible, and seems advisable, to recognize two subgenera of the genus *Cytheropteron*, one containing the typical, winged species, both fossil and Recent, and the other a number of primitive, wingless species occurring in strata of Lower Cretaceous age. Two new genera are proposed, one to receive a number of peculiar forms previously referred by most authors to *Cytheropteron*, and another to receive a large group of species, some of which have been assigned by certain authors to *Cytheropteron*, but which have generally been referred to the genus *Cythere*.

Brady and Norman, in 1892, designated *Cythere latissima* Norman, as genotype of the genus *Cytheropteron*.[5] G. O. Sars, author of the genus, evidently regards this designation as valid, since *C. latissimum* (Norman) is the first species listed under *Cytheropteron* in his recent "Account of the Crustacea of Norway."[6]

The writer is indebted to Dr. Paul Loyning, Curator of Marine Invertebrates of the Museum of the University of Oslo, Norway, for supplying specimens of *Cytheropteron latissimum* and the type species of other genera of the Ostracoda from the collections of the late Professor Sars. Without these specimens, it would not have been possible to make this study. The writer also wishes to express his gratitude to Dr. Charles Blake of the Department of Biology and Public Health, Massachusetts Institute of Technology, whose knowledge of the Recent Ostracoda and generous coöperation have been of the greatest assistance. Thanks are also due to Mr. Merle C. Israelsky, who has generously supplied the

[5] Brady, G. S., and Norman, A. M., A monograph of the marine and freshwater Ostracoda of the North Atlantic and of Northwestern Europe: *Sci. Trans. Roy. Soc. Dublin*, vol. 4, ser. 2, p. 207, 1892.

[6] Sars, G. O., An account of the Crustacea of Norway, p. 223, 1925.

writer with representatives of the species described in his paper on the Upper Cretaceous Ostracoda of Arkansas[7] and with the type specimens of two new species of *Cytheropteron* herein described.

The holotype or cotypes of the new species, and the plesiotypes of all other species will remain in the writer's personal micropaleontological collections. Metatypes of the new species and representatives of some of the other species will be deposited with the Texas State Bureau of Economic Geology at Austin, and the United States National Museum in Washington, and with Doctor A. Franke, of Arnstädt, Germany, Doctor J. H. Bonnema of the University of Gröningen, Holland, and Doctor E. Jaworski, University of Bönn, Bönn am Rhein, Germany.

The localities from which type specimens were collected will be described in a separate section at the end of the paper. The station number under which each locality is described is that by which it is identified and recorded in the writer's collections. All references to localities in the text will be made by number, with the exception of the one locality from which Israelsky collected the specimens of *Cytheropteron* which he has so kindly presented.

All illustrations for this paper were drawn by the author.

DESCRIPTION OF GENERA AND SPECIES

Order OSTRACODA Latreille

Suborder PODOCOPA Sars

Family CYTHERIDAE Baird, 1850

Genus CYTHEROPTERON Sars, 1865

Genotype CYTHEROPTERON LATISSIMUM (Norman)

Plate 25, figures 13*a*, *b*; Plate 26, figures 1*a*, *b*, 10*a*, *b*

Sars[8] characterizes the genus *Cytheropteron* as follows: "Shell of somewhat varying shape, generally thin and pellucid, with no sharply defined sculpture. Valves slightly subequal, each provided with a well defined, more or less prominent alaeform lateral expansion occurring near the ventral face. Hinge imperfectly developed." The remainder of the description is devoted to the soft parts of the animal.

On the whole, this description of the shell characters is inadequate, indefinite and unsatisfactory. Sars, like other students of the Recent Ostracoda, did not depend upon shell structure for making his generic determinations, and of course was not writing his description for the benefit of paleontologists.

The shell character upon which he seems to place the most emphasis is the presence of "alaeform lateral expansions occurring near the ventral face." Most of the species referable to the genus *Cytheropteron* do exhibit more or less strongly developed ventral wings, but there are some Lower Cretaceous species which do not. For example, *C. tumidum*[9] and *C. bilobatum*,[10] described by Alexander from the Lower Cretaceous of Texas, are roundly tumid or inflated ventrally, with no trace of alaeform expansions. In nearly all other shell characters, however, they are typical representatives of the genus. While many spe-

[7] Israelsky, M. C., Upper Cretaceous Ostracoda of Arkansas: *Ark. Geol. Survey, Bull.* 2, pp. 1–28, pls. 1A–4A. 1929.

[8] Account of the Crustacea of Norway, p. 223.

[9] Alexander, C. I., Ostracoda of the Cretaceous of North Texas: *Texas Univ. Bull.* 2907, p. 103, pl. 10, figs. 16, 17, 1929.

[10] *Ibid.*, p. 104, pl. 10, figs. 14, 15.

cies with strongly developed wings occur in the same strata with *C. tumidum* and *C. bilobatum*, it nevertheless seems probable that the winged habit was not completely established in this genus in Lower Cretaceous time, and that these, and similar species, represent early and primitive wingless types of the genus *Cytheropteron*. It is an interesting and significant fact that these wingless forms also exhibit a somewhat more primitive hinge structure than the winged species. The genus *Cytheropteron* thus seems to be divisible into two subgenera, one containing the typical, winged species, and the other the more primitive, wingless species.

Subgenus CYTHEROPTERON (G. O. Sars)

This subgenus includes the typical, winged species of the genus *Cytheropteron*. The wing-like lateral expansions of the shell which distinguish the members of this subgenus are weakly developed in some species, strongly developed in others. They are but weakly developed in the type species, *C. latissimum*.

Another feature of Sars' description of the genus *Cytheropteron* seems worthy of note. He refers to the shape of the shell as "somewhat varying." While there is of course some variation in the different species, the general shape is, on the contrary, remarkably constant in all members of the genus. The shell, as seen in side view, is ovate in outline. The dorsal margin is arched, the anterior end rounded, and the posterior end produced to form a short, blunt, narrow, compressed caudal process which curves more or less strongly upward.

The hinge (pl. 26, figs. 1*a*, *b*) consists, in the right valve, of two long, narrow, ridge-like teeth, one at each end of the hinge-line and each bearing several cusps, with corresponding notched depressions or sockets in the

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EXPLANATION OF PLATE 26

FIGS. 1*a*, *b*—*Cytheropteron* (*Cytheropteron*) *latissimum* (Norman). *a*, hinge margin of left valve; *b*, hinge margin of right valve; ×105.

2—*Cytheropteron* (*Cytheropteron*) *bicornutum* Alexander, n. sp.; left valve, lateral view.

3—*Cytheropteron* (*Eocytheropteron*) *bilobatum* Alexander; right valve view.

4*a*, *b*—*Cytheridea globosa* Alexander. *a*, Hinge margin of left valve; *b*, hinge margin of right valve; both figures ×100.

5*a*, *b*—*Cytheropteron* (*Eocytheropteron*) *bilobatum* Alexander. *a*, Hinge margin of left valve; *b*, hinge margin of right valve; both figures ×100.

6*a*, *b*—*Orthonotacythere hannai* (Israelsky). *a*, Hinge margin of left valve; *b*, hinge margin of right valve; both figures ×100.

7*a*, *b*—*Brachycythere sphenoides* (Reuss). *a*, Interior of right valve; *b*, interior of left valve, showing hinge.

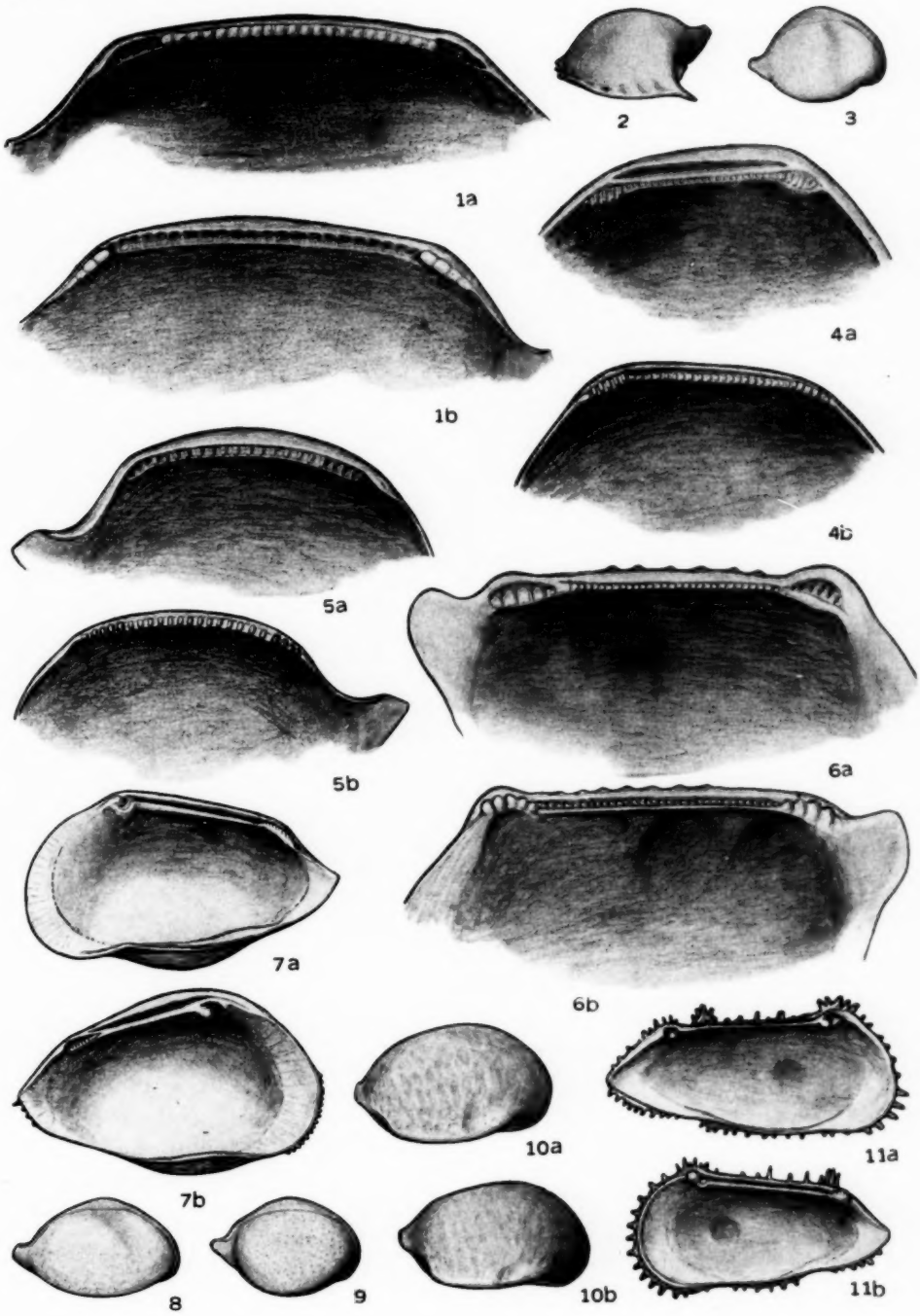
8—*Cytheropteron* (*Eocytheropteron*) *semiconstrictum* Alexander, n. sp.; right valve view.

9—*Cytheropteron* (*Eocytheropteron*) *delrioense* Alexander, n. sp.; right valve view.

10*a*, *b*—*Cytheropteron* (*Cytheropteron*) *latissimum* (Norman). *a*, Female, right valve view; *b*, male, right valve view.

11*a*, *b*—*Cythereis ornatissima* (Reuss). *a*, Interior of left valve, showing hinge; *b*, interior of right valve.

All figures ×35, unless otherwise indicated.



Alexander, Cretaceous Ostracodes

left valve. In the genotype and in other Recent species, the hinge margin of the left valve, between the terminal sockets, bears a finely serrate or crenulate ridge or bar which fits into a shallow and obscure notched furrow or groove between the terminal teeth of the right valve. In some Cretaceous species, this crenulate bar is present, but is very weakly developed and can be detected only by close scrutiny with the light from a favorable angle. The corresponding furrow does not appear to be developed at all, in these species, although there is a series of small sockets along the hinge margin of the right valve between the terminal series of teeth, corresponding to the denticles on the bar of the left valve.

The hinge structure of the genus *Cytheridea*, as previously stated, is very similar to that of *Cytheropteron*, and the similarity has lead to some erroneous generic assignments of members of the two genera. Bosquet's original description[11] of the shell characters of the genus *Cytheridea* is so accurate and clear that most students, however, both of fossil and Recent Ostracoda, have been able to properly allocate its species without difficulty. A more detailed description of the hinge structure, in order to differentiate it from that of *Cytheropteron*, may be useful, however. The hinge of *Cytheridea* is formed, in the right valve, by two long, narrow teeth, one at each end of the hinge margin, and each bearing several cusps. The anterior tooth, in most species, is larger and broader than the posterior, and the cusps are ridge-like and set at right angles to the long axis of the tooth. In the left valve are notched terminal sockets, corresponding to the teeth of the right valve. The hinge margin of the right valve bears a low, narrow, finely denticulate bar which connects the terminal teeth. A narrow bar in the left valve is attached at each end to the dorsal edge of the valve at a point just above the middle of the notched terminal sockets, but lies below and is separated by a more or less distinct groove from the margin except at the attached ends. This bar and the groove separating it from the dorsal margin of the valves are very distinct in species characterized by a short, high shell and a strongly arched dorsal margin (pl. 26, figs. 4*a*, *b*) but may be very obscure in species with a long shell and a low, flat dorsal arch. Below this bar is a faint, finely pitted groove into which the serrate bar of the right valve fits. The relation of this bar in the left valve to the dorsal edge of the valve and to the notched terminal sockets serves to differentiate the hinge structure of *Cytheridea* from that of *Cytheropteron*. The two genera are more easily differentiated, however, on the basis of general shape of the shell and on other characters than on hinge structure.

Lienenklaus has supplied a most careful and accurate description of the finer details of the shell structure of *Cytheropteron*. He describes the muscle scar pattern[12] as consisting of

[11] Bosquet, J., Description des Entomostracés fossiles de Tertiar de France et Belgique: *Mém. Acad. Roy. Sci. Belgique*, vol. 24, p. 37, 1852.

[12] Lienenklaus, E., Monographie der Ostra-

a vertical row of four small scars, located just above the middle of the ventral border, with usually a single scar in front of these, and the marginal areas[13] as moderately broad, with the radiating pore-canals few in number and widely spaced (pl. 25, figs. 13*a*, *b*). In this last named character, *Cytheropteron* differs markedly from *Cytheridea*, as in the latter genus the pore-canals are numerous and closely spaced. The writer has been unable to distinguish the muscle scar pattern of his specimens of *Cytheropteron latissimum*, but in all of the Cretaceous representatives of the genus in which the muscle scars are discernible, there are two scars in front of the vertical row of four, instead of one as stated by Lienenklaus. A few other genera of the family Cytheridae exhibit this same arrangement of the muscle scars, but further study may reveal that the shape of the individual small pits or scars is a significant generic character.

The inner margin and line of concrescence coincide except at the anterior end where the course of the inner margin is a slight distance within that of the line of concrescence.

Recent species of *Cytheropteron* exhibit marked sexual dimorphism. Male and female specimens of *C. latissimum* are figured on Pl. 26, figs. 10*a*, *b*. It is to be expected that the dimorphism is equally marked in fossil species, but a greater number of specimens of each species must be studied in order to definitely identify males and females.

koden des nordwestdeutschen Tertiärs: *Zeits. deutsch. geol. Gesell.*, vol. 46, p. 243, 1894.

[13] Lienenklaus, E., Die Tertiär-Ostrakoden des mittleren Norddeutschlands: *Zeits. deutsch. geol. Gesell.*, vol. 52, p. 541, 1900.

CYTHEROPTERON (CYTHEROPTERON) BICORNUTUM Alexander, n. sp.

Plate 25, figure 17; plate 26, figure 2

Carapace in side view ovate, highest at or slightly in front of middle. Dorsal margin strongly arched. Ventral margin very gently convex downward, nearly straight. Anterior end narrow, obliquely rounded, bearing 3–4 small, sharp teeth along lower margin. Posterior end tapering, produced to form a narrow, curved caudal process. Alaeform lateral expansions strongly developed, each with long, nearly straight, slightly convex outer margin and concave posterior margin, and each terminating posteriorly in a long, sharp, horn-like spine at the postero-lateral angle, which is directed downward, outward and backward. Each wing bears a row of 6–8 small, shallow pits near the outer margin, on both the upper and lower surfaces, and a thin, narrow, blade-like process along the middle of the concave posterior border. Lateral surface of valves smooth, finely punctate.

Length of holotype, 0.55 mm., height 0.3 mm., width 0.28 mm. (single valve).

Occurrence.—The calcareous marl beds which occur in the upper part of the Goodland formation in north Texas carry this striking species as a fairly frequent member of their microfaunas. It has been observed as a very rare form in the overlying Kiamichi shales or clays.

Holotype.—No. 0–2331.1 Alexander

Collections, collected at Station No. 2305.

CYTHEROPTERON (CYTHEROPTERON) ISRAELSKYI Alexander, n. sp.
Plate 27, figures 1*a*, *b*

Carapace in side view broadly ovate, highest near anterior end. Dorsal margin strongly arched. Ventral margin gently convex downward. Anterior end broadly and obliquely rounded. Posterior end bears a short, blunt caudal process at about the middle. Ventral, alaeform processes strongly developed, compressed, triangular in form, projecting strongly downward as well as outward, and distinctly separated from the tumid lateral surface of the valves by a shallow, longitudinal furrow at the base of each wing. A fine, narrow ridge extends downward from the small, anterior cardinal tubercle to the anterior end of this furrow. Surface of valves anterior to this ridge, finely and faintly reticulate. Posterior one-half of lateral surface of valves also finely, and somewhat more distinctly reticulate, with a narrow, smooth area between the two reticulate areas. Upper surface of each wing bears a row of 4–5 large pits, with low, rounded ridges separating the pits. Ventral surface bears two curved, longitudinally disposed ridges, which roughly parallel the outer border of the wing, the furrow between these ridges, and between the outer ridge and the margin of the wing bearing a row of large, distinct pits.

Length of holotype, 0.53 mm., height 0.27 mm., width 0.22 mm. (single valve).

Occurrence.—The writer's specimens of *C. israelskyi* were collected by Mr. Merle C. Israelsky, for whom the species is named, at an exposure of Denton clays in the bank of Messer's Creek, about 0.4 miles west of "Flag Pole Hill," 3¼ miles northeast of Denison, Texas. This is the only locality from which the species has been recorded in the writer's collections.

Holotype.—No. 0–2337.1 Alexander Collections.

CYTHEROPTERON (CYTHEROPTERON) RUGOSALATUM Alexander

Plate 25, figure 10; plate 27, figures 2*a*, *b*

Cytheropteron rugosalatum ALEXANDER, *1929*, Univ. Texas, Bull. 2907, p. 103, pl. 10, figs. 3, 4.

Carapace ovate in side view, highest near anterior end. Dorsal margin moderately arched. Ventral margin convex downward. Anterior end broadly and obliquely rounded. Posterior end somewhat narrowed and tapering, bearing a rather elongated dorsally curving caudal process near the middle. Ventral wings strongly developed, compressed, with obliquely rounded lateral or outer margins. A shallow, obscure, slightly oblique vertical furrow or sulcus divides the shell into two indistinct lobes, the posterior being slightly larger than the anterior. Lateral surface of valves smooth. Upper surface of each wing bears pits and ridges like those of the preceding species. Between the inner margin of the wings and the contact border of the valves on the ventral side are two fine, narrow, curved ridges which arise near the anterior end and roughly parallel the convex border of the wing, uniting at a point slightly behind the middle of the

valve to form a single ridge which bends abruptly outward to the inner margin of the wing and follows this backward to the posterior end.

Length of plesiotype, 0.62 mm., height 0.3 mm., width 0.24 mm. (single valve).

Occurrence.—*C. rugosalatum* is a rare form occurring most frequently in the lower Weno clays in north Texas. Occasional individuals have been observed in the Washita formations below the Weno, and in the overlying Paw Paw clays. The species also occurs in the corresponding lower and middle portions of the Georgetown formation in central and south Texas.

Plesiotype.—No. 0–2328.2 Alexander Collections, collected at Station No. 2325.

CYTHEROPTERON (CYTHEROPTERON) WENOENSE Alexander, n. sp.

Plate 25, figure 7; plate 27, figures 5*a*, *b*

Carapace in side view ovate, highest at middle. Dorsal margin moderately arched. Ventral margin convex downward. Anterior end somewhat narrowed, obliquely rounded. Posterior end tapering, bearing a long, narrow, dorsally curved caudal process near the middle. Ventral wings

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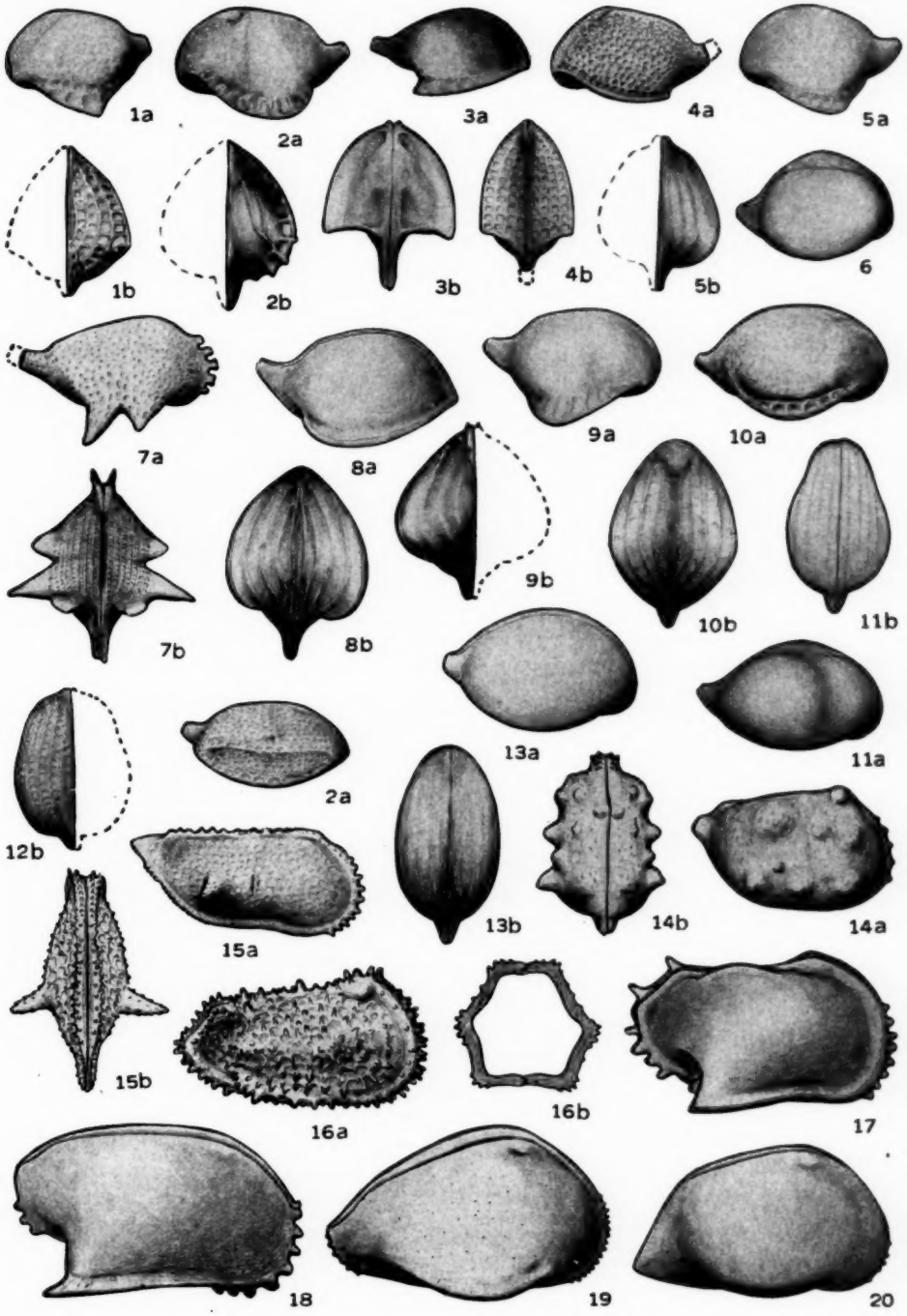
EXPLANATION OF PLATE 27

FIGS. 1*a*, *b*—*Cytheropteron* (*Cytheropteron*) *israelskyi* Alexander, n. sp. *a*, Left valve, lateral view; *b*, ventral view.
2*a*, *b*—*Cytheropteron* (*Cytheropteron*) *rugosalatum* Alexander, *a*, left valve, lateral view; *b*, ventral view.
3*a*, *b*—*Cytheropteron* (*Cytheropteron*) *acutolatum* Alexander. *a*, Right valve view; *b*, ventral view.
4*a*, *b*—*Cytheropteron* (*Cytheropteron*) *eximium* Alexander, n. sp. *a*, Left valve view; *b*, ventral view.
5*a*, *b*—*Cytheropteron* (*Cytheropteron*) *wenoense* Alexander, n. sp. *a*, Left valve, lateral view; *b*, ventral view.
6—*Cytheropteron* (*Eocytheropteron*) *paenorbiculatum* Alexander, n. sp.; right valve view.
7*a*, *b*—*Cytheropteron* (*Cytheropteron*) *furcalatum* Alexander, n. sp. *a*, Right valve view; *b*, ventral view.
8*a*, *b*—*Cytheropteron* (*Cytheropteron*) *navarroense* Alexander. *a*, Right valve view; *b*, ventral view.
9*a*, *b*—*Cytheropteron* (*Cytheropteron*) *blakei* Alexander, n. sp. *a*, Right valve view; *b*, ventral view.
10*a*, *b*—*Cytheropteron* (*Eocytheropteron*) *howelli* Alexander. *a*, Right valve view; *b*, ventral view.
11*a*, *b*—*Cytheropteron* (*Eocytheropteron*) *pirum* Alexander, n. sp. *a* Right valve view; *b*, ventral view.
12*a*, *b*—*Cytheropteron* (*Eocytheropteron*) *jugosum* Alexander, n. sp. *a*, Right valve view; *b*, ventral view.
13*a*, *b*—*Cytheropteron* (*Eocytheropteron*) *tumidum* Alexander. *a*, Right valve view; *b*, ventral view.
14*a*, *b*—*Orthonotacythere hannai* (Israeisky). *a*, Right valve view; *b*, dorsal view.
15*a*, *b*—*Monoceratina pedata* (Marsson). *a*, Right valve view; *b*, dorsal view.
16*a*, *b*—*Cythereis ornatissima* (Reuss). *a*, Right valve view; *b*, transverse section to show quadrate form.
17—*Cythereis thomasi* Israelsky; right valve view.
18—*Brachycythere alata* (Bosquet); right valve view.
19—*Brachycythere sphenoides* (Reuss); right valve view.
20—*Brachycythere ledaforma* (Israelsky); right valve view.

All figures ×35.



Alexander, Cretaceous Ostracodes

strongly developed, compressed, the outer border obliquely rounded. Upper surface of each wing bears a prominent, rounded ridge which parallels the convex outer border of the wing. Finer ridges extend radially from this longitudinal ridge inward to the base and outward to the lateral margin of the wing. Lateral surface of valves smooth. Ventral surface bears 3–4 fine, curved ridges which parallel the outer margin of the wing.

Length of holotype, 0.57 mm., height 0.3 mm., width 0.23 mm., (single valve).

This species is similar in general appearance to *C. rugosalatum*, described above, but is readily distinguished by the narrower anterior end, and the pronounced differences in the surface markings on both the upper surface of the wings and the ventral surface of the valves. The shell of *C. wenoense*, also, is not divided into lobes by a vertical sulcus, as is that of *C. rugosalatum*.

Occurrence.—*C. wenoense*, while rather rare, is a somewhat more common form than *C. rugosalatum* in the lower Weno clays, and appears to be restricted to that stratigraphic level.

Holotype.—No. 2333.1 Alexander Collections, collected at Station No. 2325.

CYTHEROPTERON (CYTHEROPTERON) ACUTOLATUM Alexander

Plate 27, figures 3*a*, *b*

Cytheropteron acutolatum ALEXANDER, *1929*, Univ. Texas, Bull. 2907, p. 104, pl. 10, fig. 7.

Carapace in side view elongate-ovate, highest in front of middle. Dorsal margin strongly arched, with steep anterior and rather gentle posterior slope. Ventral margin gently convex downward. Anterior end with acute antero-ventral angle. Posterior end tapering, narrow, produced at middle. Ventral wing-like expansions strongly developed, broad and flat, with strongly convex outer margins, acute postero-lateral angles, and concave posterior borders. Upper surface of each wing bears a single row of 4–5 small, indistinct pits near the outer margin. Lateral surface of valves smooth.

Length of plesiotype, 0.57 mm., height 0.25 mm., width 0.48 mm.

Occurrence.—*C. acutolatum* occurs as a rare form in the upper portion of the Weno and in the basal portion of the overlying Paw Paw formation.

Plesiotype.—No. 0–2324.1, collected at the type locality for the species, Station No. 2326.

CYTHEROPTERON (CYTHEROPTERON) EXIMIUM Alexander, n. sp.

Plate 27, figures 4*a*, *b*

Carapace in side view ovate, highest near anterior end. Dorsal margin arched, sloping steeply toward anterior end and flatly toward posterior end. Anterior end obliquely rounded. Posterior end bears short, blunt caudal process near middle. Ventral alaeform expansions moderately developed. Entire lateral and ventral surface of valves strongly and coarsely reticulate, the reticulations of the ventral surface arranged in distinct, parallel, longitudinal rows. This species exhibits unusually strong surface sculpture for a member of the genus *Cytheropteron*.

Length of holotype, 0.56 mm., height 0.26 mm., width 0.33 mm.

Occurrence.—*C. eximium* is a rare form, occurring in the zone of *Metoicoceras whitei* Hyatt, in the middle of the Eagle Ford formation.

CYTHEROPTERON (CYTHEROPTERON) FURCALATUM Alexander, n. sp.
Plate 27, figures 7*a*, *b*

Carapace in side view elongate-ovate, highest at anterior end. Dorsal margin gently arched. Ventral margin nearly straight, very slightly convex downward. Anterior end broadly and somewhat obliquely rounded, bearing a few broad, blunt teeth along the lower margin. Posterior end gradually tapering to a long, slender, dorsally curved caudal process. Ventral wing-like expansions of shell strongly developed, each branched laterally into two distinct parts; anterior branch flattened terminally, tapering, rounded at the end; posterior branch long, narrow, terminating in a slender needle-like spine. Lateral surface of valves finely and strongly pitted. Ventral surface with 4–5 distinct, parallel, longitudinal ridges, the furrows between each pair of ridges bearing a single row of fine pits, somewhat smaller than those which ornament the lateral surface of the valves.

Length of holotype, 0.7 mm., height 0.31 mm., width 0.68 mm.

Occurrence.—*C. furcalatum* is a characteristic member of the microfauna of the upper one-half of the Austin formation in all parts of the state. It also occurs in the lower Taylor clays and marls of south Texas, and in the Gober chalk and the underlying Brownstown marl of the northeast Texas section. It has been found to occur in nearly all samples collected within its stratigraphic range, but is nowhere very common.

Holotype.—No. 0–2480.1 Alexander Collections, collected at Station No. 2432.

CYTHEROPTERON (CYTHEROPTERON) BLAKEI Alexander, n. sp.
Plate 27, figures 9*a*, *b*

Carapace in side view ovate, highest near anterior end. Dorsal margin strongly arched, sloping more steeply toward posterior than toward anterior end. Ventral margin gently convex downward. Anterior end broadly and obliquely rounded. Posterior end bears short, blunt, rather strongly curved caudal process. Alaeform lateral expansions strongly developed, projecting distinctly downward as well as outward, and with strongly convex and obliquely curved outer margins. The carapace is broadest, and is somewhat inflated, in the posterior one-third, and is divided by a shallow, obscure median vertical sulcus, into two lobes. Lateral surface of valves smooth. Dorsal surface of each wing bears a row of shallow, obscure pits along the outer edge. Ventral surface bears four obscure, longitudinal ridges which roughly parallel the outer margin of the wing.

Length of holotype, 0.64 mm., height 0.3 mm., width 0.28 mm., (single valve).

This species was named in honor of Doctor Charles Blake, Department of Biology and Public Health,

Massachusetts Institute of Technology.

Occurrence.—*C. blakei* is represented in the writer's collections, only in the Annona chalk of northeast Texas.

Holotype.—No. 0–2481.1 Alexander Collections, collected at Station No. 24115.

CYTHEROPTERON (CYTHEROPTERON) NAVARROENSE Alexander

Plate 25, figure 4; plate 27, figures 8*a*, *b*

Cytheridea (?) *saratogana* ISRAELSKY, *1929*, Ark. Geol. Survey, Bull. 2, p. 11, pl. 2A, figs. 7–9.

Cytheropteron navarroense ALEXANDER, *1929*, Univ. Texas, Bull. 2907, p. 105, pl. 10, figs. 5, 6.

Carapace in side view ovate, highest slightly in front of middle. Dorsal margin strongly and evenly arched. Ventral margin gently convex downward. Anterior end low, narrow, with blunt antero-ventral angle. Posterior end somewhat tapering, with short, blunt, rather strongly curved caudal process. Ventral wing-like expansions of shell strongly developed, flattened, with strongly and almost evenly convex outer margins. Lateral surface of valves smooth. Ventral surface of each valve bears four fine, but prominent longitudinal ridges which roughly parallel the outer margin of the wing.

Length of plesiotype illustrated on plate 27, fig. 8, 0.74 mm., height 0.35 mm., width, 0.5 mm.

While the name applied by Israelsky to this species was published a few weeks before that applied by the present writer, it cannot, according to the International Rules of Zoological Nomenclature, be accepted as a valid name. The species is obviously a representative of the genus *Cytheropteron*, and the name *Cytheropteron saratogana* was used by Israelsky on an earlier page of his paper[14] to describe a species herein referred to the genus *Brachycythere*, new genus, and identified specifically with *B. alata* (Bosquet).

Occurrence.—Israelsky records this species as occurring in the Saratoga chalk in Arkansas. In the Texas section, it occurs in the Navarro clays, and has been collected at exposures of this formation in all parts of the state.

Plesiotypes.—Specimen figured in Pl. 25, fig. 4, No. 0–2476.2, and specimen figured in Pl. 27, figs. 8*a*, *b*, No. 0–2476.1 Alexander Collections, collected at Station No. 2460.

Subgenus EOCYTHEROPTERON, new

Subgenotype: CYTHEROPTERON BILOBATUM Alexander

The shell structure of this subgenus is in nearly all respects similar to that of the subgenus *Cytheropteron*. The most obvious differences are that the representatives of the subgenus *Eocytheropteron* are roundly tumid or inflated ventrally, and do not bear any trace of wing-like lateral expansions, and that the left valve is usually distinctly larger than the right, and overlaps it conspicuously along the dorsal margin. The hinge structure is also slightly different from that of the subgenus *Cytheropteron*, and according to this writer's interpretation, more primitive. The right valve

[14] Israelsky, M. C., Upper Cretaceous Ostracoda of Arkansas: *Ark. Geol. Survey, Bull.* 2, p. 10, pl. 2A, figs. 4*a–c*, 1929.

bears a series of small teeth on short, ridge-like elevations at each end of the hinge margin, with corresponding notched sockets in the left valve, but there is no crenulate bar connecting the terminal sockets of the left valve, as in *Cytheropteron*. The hinge margin of each valve, on the other hand, between the terminal series of teeth of the right, and the terminal sockets of the left valve, is finely denticulate, the teeth of one valve fitting into sockets between the teeth of the other valve. The teeth of the median series of the two valves are but slightly smaller than those of the two terminal series of the right valve. The strongly overhanging dorsal edge of the large, left valve causes the median teeth of this valve to appear to be located in a deep groove (See pl. 26, figs. 5*a*, *b*).

In all other shell characters, the members of the two subgenera are entirely similar.

CYTHEROPTERON (EOCYTHEROPTERON) BILOBATUM Alexander

Plate 25, figure 11; plate 26, figures 3, 5*a*, *b*

Cytheropteron bilobatum ALEXANDER, *1929*, Univ. Texas, Bull. 2907, p. 104, pl. 10, figs. 14, 15.

Carapace broadly ovate, highest at middle. Dorsal margin strongly arched. Ventral margin gently convex downward. Anterior end broadly and obliquely rounded. Posterior end bears a short, blunt, compressed, rather strongly curved caudal process. Valves inflated and roundly tumid ventrally. A broad, shallow sulcus divides the carapace into two unequal lobes, the posterior lobe being slightly larger than the anterior. Surface of valves smooth, finely punctate.

Length of plesiotype, 0.48 mm., height 0.33 mm., width 0.25 mm.

Occurrence.—This species is very abundant in Weno clays in the vicinity of Denison, Texas, but has not been observed by the writer in samples collected from any other horizon or localities. Mr. Merle C. Israelsky has sent the writer specimens which he describes as occurring in the Weno of Oklahoma, as exposed 3.5 miles north of Durant.

Plesiotypes.—No. 0–2325.1 Alexander Collections, collected at Station No. 2329.

CYTHEROPTERON (EOCYTHEROPTERON) HOWELLI Alexander

Plate 27, figures 10*a*, *b*

Cytheropteron howelli ALEXANDER, *1929*, Univ. Texas, Bull. 2907, p. 103, pl. 10, figs. 1, 2.

Carapace in side view ovate, highest at middle. Dorsal margin evenly arched. Ventral margin gently convex downward. Anterior end broadly and somewhat obliquely rounded. Short, blunt caudal process near middle of posterior margin. Valves strongly convex. Tumid ventral portion of valves with a thick, elevated, longitudinal ridge which bears a single row of 6–8 large, deep pits. Lateral surface of valves in well preserved specimens exhibits faint reticulation. Ventral surface bears four fine, longitudinal ridges, roughly paralleling the outer border of the ventral surface; these longitudinal ridges are connected by numerous, obscure, cross-ridges.

Length of plesiotype, 0.68 mm., height 0.34 mm., width 0.45 mm.

Many individuals of this species

do not have as strongly elevated and deeply pitted a ventral longitudinal ridge as do the holotype and the plesiotype figured here.

Occurrence.—*C. howelli* has been found to occur in the upper portion of the Goodland and in the overlying Kiamichi formation of the Lower Cretaceous of Texas.

Plesiotype.—No. 0–2326.1 Alexander Collections, collected at Station No. 2302, the type locality for the species.

CYTHEROPTERON (EOCYTHEROPTERON) PIRUM Alexander, n. sp.

Plate 27, figures 11*a*, *b*

Carapace in side view, distinctly elongate, ovate. Dorsal margin strongly arched. Ventral margin almost straight, very slightly convex downward. Anterior end narrowed, obliquely rounded. Posterior end tapering to subacute caudal process slightly below middle. Valves strongly convex, tumid ventrally. In dorsal view, the shell is pear-shaped the posterior half being more strongly inflated than the anterior. Lateral surface of valves smooth, finely punctate. Ventral surface bears several fine, longitudinal ridges.

Length of holotype, 0.65 mm., height 0.38 mm., width 0.37 mm.

Occurrence.—*C. pirum* occurs as a rare form in the Goodland and Kiamichi formations of the Lower Cretaceous of north Texas.

Holotype.—No. 0–2329.1 Alexander Collections, collected at Station No. 2302.

CYTHEROPTERON (EOCYTHEROPTERON) PAENORBICULATUM Alexander, n. sp.

Plate 25, figure 8; plate 27, figure 6

Carapace in side view broadly ovate, almost circular in outline. Dorsal margin strongly arched, highest at middle. Ventral margin moderately convex downward. Anterior end broadly and obliquely rounded. Compressed caudal process below middle of posterior margin. Carapace moderately convex, roundly tumid ventrally; in dorsal view ovate, widest slightly behind middle. Lateral surface of valves smooth. Ventral surface bears four fine, parallel longitudinal ridges.

Length of holotype, 0.55 mm., height 0.37 mm., width 0.32 mm.

The distinguishing characteristic of this small species is the unusually high ratio of height to length of the carapace.

Occurrence.—*C. paenorbiculatum* is very common at some levels in the Goodland, and the writer has specimens collected by M. C. Israelsky from the Kiamichi formation in Denton County, Texas.

Holotype.—No. 0–2330.1 Alexander Collections, collected at Station No. 2302.

CYTHEROPTERON (EOCYTHEROPTERON) TUMIDUM Alexander

Plate 27, figures 13*a*, *b*

Cytheropteron tumidum ALEXANDER, *1929*, Univ. Texas, Bull. 2907, p. 103, pl. 10, figs. 16, 17.

Carapace in side view ovate, highest slightly in front of middle. Dorsal margin evenly arched. Ventral margin convex downward. Anterior end slightly narrowed, obliquely rounded.

Caudal process short, narrow, near middle of posterior margin. Valves moderately convex, roundly tumid ventrally. Lateral surface of valves obscurely pitted or reticulate. Ventral surface bears 3–4 fine, straight, parallel longitudinal ridges.

Length of plesiotype, 0.69 mm., height 0.44 mm., width 0.37 mm.

Occurrence.—*C. tumidum* is common in outcrops of the Kiamichi formation in north Texas, and occurs as a rare form in the underlying Goodland.

Plesiotype.—No. 0–2327.1 Alexander Collections, from the type locality for the species, Station No. 2305.

CYTHEROPTERON (EOCYTHEROPTERON) SEMICONSTRICTUM Alexander, n. sp.
Plate 26, figure 8

Carapace in side view ovate. Dorsal margin strongly arched, highest and obscurely angled at middle, sloping more steeply toward posterior than toward anterior end. Ventral margin very gently convex downward. Anterior end narrowed, low, obliquely rounded. Caudal process below middle of posterior margin, the inferior border of the process forming an almost unbroken curve with the gently convex ventral margin of the shell. Valves strongly convex, roundly tumid ventrally. A shallow, obscure sulcus runs obliquely downward and forward from the highest point of the dorsal arch to about the level of the median longitudinal line of the carapace. Surface of valves finely and faintly reticulate, the reticulations arranged in distinct longitudinal rows on the lower portion of the lateral surface. Ventral surface with four fine, parallel longitudinal ridges. Carapace in dorsal view ovate, widest behind the middle.

Length of holotype, 0.59 mm., height 0.33 mm., width 0.35 mm.

Occurrence.—*C. semiconstrictum* appears to be restricted to the Kiamichi formation in north Texas.

Holotype.—No. 0–2332.1 Alexander Collections, collected at Station No. 2305.

CYTHEROPTERON (EOCYTHEROPTERON) JUGOSUM Alexander, n. sp.
Plate 27, figures 12*a*, *b*

Carapace in side view elongate-ovate, highest anterior to middle. Dorsal margin evenly arched. Ventral margin gently convex downward. Anterior end obliquely rounded. Short, blunt caudal process near middle of posterior margin. Valves very strongly convex. Tumid ventral portion of valves bears a thickened, strongly elevated longitudinal ridge. A second, somewhat less prominent longitudinal ridge lies slightly below the median longitudinal line of the valves, and is separated from the ventral ridge by a broad, deep furrow. Entire lateral surface of valves strongly and coarsely reticulate, each of the longitudinal ridges bearing a single row of pits slightly larger than those covering the lateral surface. Ventral surface of valves with five fine, longitudinal ridges, the furrows between these ridges being finely pitted.

Length of holotype, 0.62 mm., height (right valve) 0.3 mm., width 0.22 mm., (single valve).

Occurrence.—The writer's speci-

mens were collected by Mr. Merle C. Israelsky, from an exposure of Denton clay on Messer's Creek, about 0.4 miles west of "Flag Pole Hill," 3¼ miles northeast of Denison, Texas.

Holotype.—No. 0–2338.1, Alexander Collections.

CYTHEROPTERON (EOCYTHEROPTERON) DELRIOENSE Alexander, n. sp.

Plate 25, figure 12; plate 26, figure 9

Carapace in side view broadly ovate. Dorsal margin strongly arched, highest at middle. Ventral margin convex. Anterior end somewhat narrowed, obliquely rounded. Caudal process slightly below middle of posterior margin, narrow, distinctly curved. Carapace moderately convex, roundly tumid ventrally. In dorsal view, ovate, widest at middle. Lateral surface of valves smooth, finely pitted or punctate, granular in appearance. Ventral surface with five fine, parallel longitudinal ridges on each valve.

Length of holotype 0.53 mm., height 0.33 mm., width 0.28 mm.

C. delrioense is very similar in appearance to *C. paenorbiculatum* from the Goodland and Kiamichi formations, but is relatively somewhat narrower in side view, has a narrower, more obliquely rounded anterior end, and a distinctly granular surface rather than a perfectly smooth and unpitted one.

Occurrence.—*C. delrioense* has been found only in the Del Rio clays in south Texas.

Holotype.—No. 0–2347.1 Alexander Collections, collected at Station No. 2361.

Genus ORTHONOTACYTHERE new genus

Genotype: CYTHERIDEA (?) HANNAI Israelsky

This new genus is proposed for a number of fossil species which have been assigned to the genus *Cytheropteron*, but which seem to differ sufficiently to deserve separate generic distinction.

The most obvious and striking differences are in the shape of the shell and the surface sculpture of the valves. The members of this new genus are very similar in many respects to species of the genus *Monoceratina* Roth.[15] *Orthonotacythere* is, in fact, believed to have been derived from *Monoceratina*.

Roth, in his original description of *Monoceratina*, assigns it to the family Primitiidae, but certain features of shell structure seem to indicate its affiliation with the family Cytheridae. The reasons for this assignment and the shell characters of *Monoceratina* will be discussed on a later page.

Species of the genus *Orthonotacythere* are characterized by a roughly quadrate outline. The dorsal margin is straight, or nearly straight. It may be slightly sinuate at the middle or very slightly irregular, but is never arched or convex. The ventral margin in some species is straight, in others more or less convex downward, but in all, tends to parallel the dorsal margin. The anterior end is broadly rounded, denticulate, and in some species, bears a thickened or elevated marginal ridge. The posterior

[15] Roth, R. A., *Monoceratina*, A new genus of Ostracoda from the Pennsylvanian of Oklahoma: *Jour. Paleontology*, vol. 2, p. 15, 1928.

end bears a short, narrow, compressed caudal process, which is situated at or very near the postero-dorsal angle of the shell. The carapace is characteristically widest and more or less tumid ventrally. Lateral alaeform expansions are never present. The surface is marked by numerous strong tubercles. The number and arrangement of the tubercles varies in different species. The surface of some species, except for the tubercles, is smooth, but in most it is strongly sculptured with pits, reticulation, spines and ridges.

In other shell structures, members of this genus are very close to *Cytheropteron*. The hinge (pl. 26, figs. 6*a*, *b*) consists, in the right valve, of two teeth, one at each end of the hinge line, and each bearing several cusps, with corresponding notched sockets in the left valve. The dorsal margin of the left valve, between the terminal sockets, bears a fine, minutely denticulate ridge or bar which fits into a shallow, notched furrow between the terminal teeth of the right valve. This hinge structure is identical with that of the typical *Cytheropteron*, except that it is longer, the terminal teeth of the right, and the terminal sockets of the left valve being at opposite ends of the straight dorsal margin, which extends the full length of the shell, exclusive of the caudal process. The muscle scar pattern (pl. 25, fig. 1*c*) consists, as in the Cretaceous species of *Cytheropteron* and in many other genera of the family Cytheridae, of a single vertical row of small scars situated near the median-longitudinal line of the valves, but distinctly in front of the middle, with two other scars in front of these. The shape of the individual scars making up the pattern will be seen to differ, at least in the species figured, from those of *Cytheropteron*. Further and more detailed studies of the muscle scars of several species of each genus of the family Cytheridae will be necessary in order to determine whether the shape of the small pits composing the muscle scar pattern can be used in recognizing genera.

The line of concrescence is at a moderate distance from and parallel to the outer margin of the shell. The inner margin and line of concrescence coincide throughout. The radial pore-canals are few in number and widely spaced, straight, and simple (pl. 25, figs. 1*a*, *b*).

Several species of *Orthonotacythere* have been recognized by the writer in the Cretaceous of Texas. The different species are easily recognized, and occur in fairly restricted stratigraphic ranges. These species, and some Cretaceous species of the genus *Monoceratina* will be described in a later paper, now in preparation.

ORTHONOTACYTHERE HANNAI (Israelsky)
Plate 25, figures 1*a–c;* plate 26, figures 6*a*, *b;* pate 27, figures 14*a*, *b*

Cytheridea (?) *hannai* ISRAELSKY, *1929*, Ark. Geol. Survey, Bull. 2, p. 12, pl. 2A, fig. 10.
Cytheropteron hannai ALEXANDER, *1929*, Univ. Texas, Bull. 2907, p. 105, pl. 9, fig. 16.

Shell broadly ovate, highest at anterior end. Dorsal margin long, straight. Ventral margin convex downward. Anterior end broadly and obliquely rounded, bearing 6–8 short, blunt teeth. A low, obscure ridge near the anterior margin parallels the mar-

gin and bears 4–5 small teeth or tubercles along its lower one-half. The convex ventral margin swings sharply upward near the posterior end, to the short, blunt, compressed caudal process near the postero-dorsal angle. A shallow, obscure vertical sulcus divides the carapace into two unequal lobes, the posterior lobe being slightly larger and more tumid than the anterior. Surface of carapace rough, bearing eight distinct, rounded tubercles, the surface between the tubercles finely and strongly reticulate or pitted. Three tubercles near the ventral margin are more prominent than the others; one is near the ventral edge of the anterior lobe of the carapace, another, somewhat higher than the first, is at the lower end of the vertical furrow or sulcus, and the third and most strongly elevated of the three is near the ventral edge of the posterior lobe. About half way between the posterior pair of the three ventral tubercles, and above them, slightly below the median-longitudinal line of the valve, is a small tubercle, and above this, near the middle of the dorsal edge of the posterior lobe of the carapace, is a very broad, low tubercle which bears several smaller tubercles upon it. The anterior lobe bears, in addition to the large, ventral tubercle, three smaller ones. Two of these form, with the large, dorsal tubercle of the posterior lobe, a slightly oblique longitudinal row, the anterior one of the series lying near the anterior edge of the anterior lobe, and but slightly above the median longitudinal line of the valve. The third small tubercle of the anterior lobe is the anterior cardinal tubercle, situated over the anterior end of the hinge line.

Length of plesiotype, 0.67 mm., height 0.42 mm., width 0.45 mm.

Israelsky's original figure of this species is generalized, and shows far too many tubercles. Alexander's figure of a specimen from the Navarro formation of Texas fails to indicate clearly the position of all the surface markings. The figures here published have been very carefully drawn, and are as accurate, to the finest detail, as it has been possible to make them.

Two other species of *Orthonotacythere*, very similar in appearance to *O. hannai*, occur in the Taylor strata in Texas, but are characterized by less strongly convex shells, by distinctly different arrangement of the tubercles, and by other differences in the surface markings. These species will be described and figured in a forthcoming paper on species of the genus *Orthonotacythere*.

Occurrence.—Israelsky describes *O. hannai* as occurring in the Ozan formation of Arkansas, which is correlative with the Taylor clays immediately underlying the Pecan Gap chalk member of the Taylor formation, or that stratigraphic level, in the Texas section. Representatives of this species are very rare in outcrops of Taylor and its stratigraphic equivalents in Texas, but are somewhat more numerous in the overlying Navarro clays. The Navarro specimens are, as a rule, slightly larger than those from the Taylor, and from the Ozan of Arkansas, but the general proportions of the carapace and the

arrangement of the surface tubercles are precisely the same, and the two forms must be regarded as specifically identical. Through the courtesy of Mr. Merle C. Israelsky, the writer has had the opportunity of examining specimens from the Ozan clays of Arkansas.

Plesiotypes (*Genocotypes*).—Specimen figured on plate 25, figs. 1*a*, *b*, No. 2477.2 Alexander Collections; other specimens, No. 2477.1 Alexander Collections. All figured specimens collected at Station No. 2460.

Genus MONOCERATINA Roth, 1928

Genotype: MONOCERATINA VENTRALE Roth

Carapace in side view quadrate, distinctly elongate. Dorsal margin straight. Ventral margin straight or slightly convex, paralleling the dorsal margin. Anterior end rounded, in some species bearing marginal spines or denticles and a marginal ridge. Posterior end tapering, bearing a more or less distinctly produced, compressed caudal process near the postero-dorsal angle. Carapace moderately convex in some species, strongly convex in others, and commonly divided into subequal lobes by a more or less distinct vertical sulcus, which is situated at or near the median vertical line of the shell. Carapace widest at or below the middle, commonly widest at ventral margin. One of the most distinctive characters of the genus is the presence of a strong, horn-like, laterally projecting spine on the valves. The position of this spine varies in different species, but is characteristically located at or near the ventral margin, and slightly behind the middle. In addition to this prominent spine, from which the genus takes its name, the surface may bear other shorter spines, tubercles and ridges, and is usually distinctly pitted or reticulate.

The hinge structure is simple, and consists of a narrow bar in the left valve which fits into a slight groove or furrow in the right valve.

The line of concrescence and inner margin coincide throughout, and their course is near and parallel to the outer margin of the shell. The radial pore-canals could not be observed in any specimens examined by the writer.

The strong surface ornamentation also made it impossible to determine the arrangement of the muscle scars.

The genotype, *M. ventrale* Roth, was collected from the Wapanucka limestone, of Pennsylvanian age, in Oklahoma.[16] The genus appears to reach its greatest development, however, in the Upper Cretaceous. Several species of *Monoceratina* have been described by various authors, under the names *Cythere* and *Cytheropteron* from Cretaceous strata in many parts of the world. Through the courtesy of Dr. Reginald Harris, of the Department of Geology, University of Oklahoma, the writer has recently had the opportunity of comparing specimens of *Monoceratina* from the Pennsylvanian of Oklahoma with others from the Cretaceous of Texas and Europe. There can be no doubt of the generic identity of the Pennsylvanian and Cretaceous species.

[16] Roth, R., *op. cit.*, p. 16.

The presence of the compressed caudal process and the presence in some species of an anterior marginal rim, structures which are characteristic of several genera of the family Cytheridae, and are unknown in the Primitiidae indicate that Roth's assignment of the genus to the latter family is erroneous, and that actually it belongs to the former.

Roth's description also confuses the anterior and posterior ends of the carapace, and erroneously infers that the horn-like lateral processes are associated with the soft parts of the animal.

MONOCERATINA PEDATA (Marsson)
Plate 27, figures 15*a*, *b*

Cythere pedata MARSSON, *1880*, Mittheil. naturwiss. Verein. von Neu-Vorpommern und Rugen in Greifswald, p. 46, pl. 3, figs. 16, *a–c*.

Cytheropteron pedatum JONES and HINDE, *1889*, Suppl. Monogr. Cret. Entom. Engl. Irel., Paleontogr. Soc. London, p. 38, pl. 4, figs. 33–35.

Cytherura spooneri ISRAELSKY, *1929*, Ark. Geol. Survey, Bull. 2, p. 6, pl. 4A, figs. 7*a*, *b*.

Carapace in side view elongate, subquadrate, highest at anterior end. Dorsal margin straight. Ventral margin nearly straight, slightly sinuate at middle. Dorsal and ventral margins nearly parallel, converging slightly posteriorly. Anterior end broadly and obliquely rounded, bearing a narrow, elevated marginal rim. Entire margin of valves densely and finely spinose, the spines of the anterior end being somewhat larger than those of the dorsal and ventral margins. Posterior end tapering, with short, compressed acute caudal process at postero-dorsal angle. Valves moderately convex, carapace widest behind middle. Each valve bears, near the posterior one-third of its length and slightly below the middle, a long, sharp, laterally-projecting, needle-like spine which is directed slightly backward and downward. This spine is closely beset with numerous smaller spines. Surface of valves strongly pitted or reticulate, and bearing numerous, short, sharp spines which arise at the points of union of the reticular ridges.

Length of plesiotype, 0.85 mm., height 0.38 mm., width 0.55 mm.

Mr. Merle C. Israelsky has generously supplied the writer with a specimen of his *Cytherura spooneri* from the Ozan formation of Arkansas. Through the courtesy of Dr. William Kegel, of Berlin, Germany, the writer has obtained a sample of the "White Chalk of Rugen," type locality for Marsson's *Cythere pedata*. The two forms are identical in every detail, as is amply demonstrated by the published figures.

Occurrence.—Israelsky describes this species as occurring in the Ozan and Brownstown marls of Arkansas. In the writer's collections, *M. pedata* is represented most frequently in the chalky facies, occurring in the Gober and Annona chalks of northeast Texas, and in the Annona and Saratoga chalks of Arkansas. It has not been observed in the Austin chalk of the type section, but occurs as a very rare form in calcareous clays of lower Taylor age in south and central Texas. The form and distinctive surface marking of this species make it a very easy one to recognize, but the fact that it occurs through a wide

stratigraphic range, and that it is rather rare wherever it has been observed, detract greatly from its value as a stratigraphic marker.

Plesiotype.—No. 0–2478.2 Alexander Collections, collected at Station No. 24115.

Genus BRACHYCYTHERE new genus

Genotype: CYTHERE SPHENOIDES Reuss

This new generic name is proposed for a large number of species, both fossil and Recent, which have been generally regarded as members of the genus *Cythere* Müller, 1785. Indeed, a survey of the literature, especially paleontological literature, will show that the common conception of the shell structure of the genus *Cythere* is based on species of this group, rather than upon the type species.

Dr. Charles Blake has recently described and figured in great detail, the shell structure of the genotype of the genus *Cythere*, *C. lutea* Müller, and concludes that *Cythere*, as properly defined, includes "probably fewer than ten species, Recent and fossil."[17] It is certain that the many species for which this new generic name is here proposed are not congeneric with *C. lutea*.

The writer submitted specimens of *Cythere sphenoides* Reuss, which has been selected as genotype for this new genus, to Dr. Blake, in order to ascertain if it might be referable to any of the other genera of the family Cytheridae having Recent species as genotypes. Dr. Blake has written, under date of May 11, 1932, that *C. sphenoides* can definitely be excluded from all these genera except *Cytheromorpha* Hirschmann, 1901, "in which the shell structure is unknown." Among the specimens secured by the writer through Dr. Paul Loyning of the University of Oslo, are representatives of *C. fuscata* (Brady), type species of the genus *Cytheromorpha*. *Cythere sphenoides* and *Cytheromorpha fuscata* differ markedly in all important features of shell structure, and it thus seems that *Cythere sphenoides* and a number of closely similar forms, properly constitute a distinct and separate group, deserving generic recognition.

The generic characters of this new genus are very distinctive, and exhibit but very slight variation among the large number of species referable to the genus.

The carapace is usually oblong-ovate to oblong-quadrate in outline. The dorsal margin is more or less strongly arched, (never straight or irregular) and is commonly highest at or somewhat anterior to the middle. The anterior end is compressed, broadly and obliquely rounded, never bears a distinctly thickened marginal rim, and is commonly denticulate along the outer margin. The posterior end is likewise compressed, is narrower than the anterior, and may be rounded or more or less acute, and like the anterior end is usually denticulate. The left valve is conspicuously larger than the right, and overlaps it strongly along the entire dorsal margin, and less distinctly along the other portions of the periph-

[17] Blake, Charles, Notes on Ostracoda: *Jour. Paleontology*, vol. 5, p. 160, figs. 1*b–e*, 1931

ery. The surface, in most species, is smooth or finely punctate, but in some is ornamented with pits, reticulations, tubercles and ridges. In most species a distinct, low, rounded anterior cardinal tubercle is present, over the anterior end of the hinge line. The carapace is strongly convex, and is widest ventrally; the ventral surface is broad, and in most species is flat, or nearly so (pl. 25, fig. 14*a*), giving the carapace a triangular appearance in end view or in transverse section. Some species bear strong wing-like processes at the ventrolateral edge of the valves, and members of the genus have therefore been assigned by some authors to the genus *Cytheropteron*. It is for this reason, in fact, that the group is treated here.

The hinge structure consists, in the right valve, of a strong, rounded, knob-like anterior tooth, and a long, flat, compressed, ridge-like, finely serrate or crenulate posterior tooth. Immediately behind the anterior tooth is a deep socket. The hinge margin, between this socket and the posterior tooth, bears a shallow, but distinct groove or furrow, the dorsal edge of the valve projecting as a low ridge above this furrow (pl. 26, fig. 7*a*). Corresponding to the anterior tooth and postjacent socket of the right valve, the hinge margin of the left valve bears a deep anterior socket and immediately behind it, a strong, knob-like tooth. A strong ridge or bar, which is below and free of the dorsal margin of the shell and separated from it by a deep and distinct groove, extends posteriorly from this tooth, and joins the dorsal margin of the valve in front of the long, narrow, notched socket which corresponds to the serrate posterior tooth of the right valve (pl. 26, fig. 7*b*).

The muscle scar area is located slightly in front of the middle, and exhibits a very distinctive and characteristic pattern, which is illustrated in Plate 25, fig. 3*c*.

The marginal zones of the shell (Plate 25, figs. 3*a*, *b*) are moderately broad. The radiating pore-canals are numerous, and closely spaced, especially in the anterior and anteroventral region, where they are frequently branching and anastomosing. Most of the canals are somewhat widened near the margin of the shell. The inner margin and line of concrescence coincide throughout.

Two species, including one strongly alate form, will be described and figured, in addition to the genotype, in order to illustrate the degree of variation in shell structure and form occurring within the generic group.

BRACHYCYTHERE SPHENOIDES (Reuss)

Plate 25, figures 3*a–c*, 14*a*, *b*; plate 26, figures 7*a*, *b*; plate 27, figure 19

Cythere sphenoides REUSS, *1854*, Denkschr. Kais. Akad. Wissen. Wien, vol. 7, p. 141, pl. 26, fig. 2; ALEXANDER, *1929*, Univ. Texas, Bull. 2907, p. 81, pl. 7, figs. 9, 14.

Cytheropteron sphenoides JONES and HINDE, *1889*, Suppl. Monogr. Cret. Entom. Eng., Irel., Paleontogr. Soc. London, p. 33, pl. 1, figs. 18–20.

Cytheropteron sp. B. ISRAELSKY, *1929*, Ark. Geol. Survey, Bull., 2, p. 8, pl. 1A, figs. 2*a–c*.

Carapace in side view ovate, highest anterior to middle. Height equal to slightly more than two-thirds of length. Dorsal margin arched, ending posteriorly in an obscure angle. Dorsal and ventral margins converge

strongly toward posterior end. Anterior end compressed, broadly and obliquely rounded, densely and finely denticulate. Posterior end compressed, narrow, low, rounded and finely denticulate below, obliquely truncated above. Valves strongly convex, widest slightly behind middle. Ventral surface broad and flat. Ventro-lateral edge of each valve bears a low, narrow, rounded ridge. Surface finely and discretely punctate.

Length of plesiotype figured on Plate 27, fig. 9, 1.0 mm., height 0.6 mm., width 0.48 mm.

The longitudinal ridge which marks the ventro-lateral edge of the valves of *B. sphenoides* is broader and more strongly elevated in most specimens collected from strata near the upper limit of the species' stratigraphic range, than in those collected at lower levels. This tendency toward increase in the prominence of the ventro-lateral ridge culminates in the upper Taylor in the development of a rare, unnamed form in which the ridge is so strongly developed as to constitute a basis for specific separation, and in the characteristic Navarro species *B. rhomboidalis* (Berry), which is distinguished by a high, broad ventral ridge which bears a single, longitudinal row of small pits.[18]

Occurrence.—*B. sphenoides* is a common form occurring from base to top of the Austin, and upward through the lower one-half of the overlying Taylor formation in south, central and north Texas, and in the corresponding formations up to and including the Annona chalk in northeast Texas. The species occurs in greatest abundance in the upper Austin and in most outcrops of lower Taylor, but becomes increasingly rare toward the upper limit of its stratigraphic range. It is not represented in collections from strata above the Wolfe City sand member of the Taylor formation in north Texas, or above that stratigraphic level in central and south Texas.

Plesiotypes (*Genocotypes*).—Specimens figured on Plate 25, figs. 14*a*, *b*, Plate 26, figs. 7*a*, *b*, and Plate 27, fig. 19, No. 0–2474.1 Alexander Collections, collected at Station No. 24113; specimen figured on Plate 25, fig. 3*c*, No. 0–2474.2 Alexander Collections, collected at Station No. 24124: specimen figured on Plate 25, figures 3*a*, *b*, No. 0–2474.3 Alexander Collections, collected at Station No. 24113.

BRACHYCYTHERE LEDAFORMA (Israelsky)
Plate 25, figure 9; plate 27, figure 20

Cytheropteron ledaforma ISRAELSKY, *1929*, Ark. Geol. Survey, Bull. 2, p. 8, pl. 1A, figs. 5–7.

Cythere acutocaudata ALEXANDER, *1929*, Univ. Texas, Bull. 2907, p. 87, pl. 7, figs. 5, 6.

Carapace in side view oblong-ovate, highest near anterior end. Dorsal margin arched, nearly straight along hinge line. Ventral margin gently convex downward. Dorsal and ventral margins converge somewhat posteriorly. Anterior end compressed, obliquely rounded, bearing a few fine teeth along the lower part of the peripheral margin. Posterior end strongly compressed, somewhat produced, obliquely truncated, with

[18] Alexander, C. I., Ostracoda of the Cretaceous of North Texas, *Univ. Texas, Bull.* 2907, 1929, p. 86, pl. 7 figs. 1, 2.

actute postero-ventral angle. Valves strongly convex, widest and roundly tumid ventrally. Lateral surface of valves smooth; tumid ventral surface marked by several fine, closely-spaced, parallel longitudinal ridges.

Length of plesiotype, 0.9 mm., height 0.55 mm., width 0.52 mm.

Occurrence.—Israelsky's cotypes for *B. ledaforma* are from the Saratoga chalk of Arkansas, and he records the species as occurring in the overlying Nacotoch sand and in the underlying Marlbrook marl. In the Texas section, it is a common form in the lower two-thirds of the Navarro formation. A closely similar species occurs in the Taylor clay, but is smaller in size, and exhibits, on the lateral surface of the valves near the ventral edge, a group of small, but rather deep pits.

Plesiotype.—No. 0–2470.1 Alexander Collections, collected at Station No. 2460.

BRACHYCYTHERE ALATA (Bosquet)
Plate 25, figures 15*a*, *b*; plate 27, figure 18

Cypridina alata BOSQUET, *1847*, Mém. Soc. Roy. Sci., Liége, vol. 4, p. 369, pl. 4, figs. 1*a–d*.
Cythere alata BOSQUET, *1854*, Mém. Comm. Carte geol. Neerlande, vol. 2, p. 117, pl. 9, figs. 10*a–d*.
Cytheropteron alatum JONES and HINDE, *1889*, Suppl. Monogr. Cret. Entom. Eng., Irel., Paleontogr. Soc. London, p. 34.
Cytheropteron saratogana ISRAELSKY, *1929*, Ark. Geol. Survey, Bull. 2, p. 10, pl. 2A, figs. 4*a–c*.
Cythere cornuta (F. A. ROEMER) var. *gulfensis* ALEXANDER, *1929*, Univ. Texas, Bull. 2907, p. 85, pl. 8, figs. 1, 2, 6.

Carapace in side view oblong, subquadrate, highest in front. Height equal to about one-half of length. Dorsal margin gently and evenly convex. Ventral margin straight. Dorsal and ventral margins subparallel, converging slightly posteriorly. Anterior end compressed, with narrow, flat marginal rim, broadly and obliquely rounded, and bearing six to eight long, strong, flattened teeth. Posterior end narrower than anterior, obliquely rounded, and bearing five to six long, strong, spine-like teeth. Valves bear strongly-projecting, compressed, alaeform lateral expansions at the ventral margin. The outer or lateral border of each wing is nearly straight, the posterior border slightly concave, and the postero-lateral angle bears a strong, tapering, slightly curved spine. Surface of valves smooth.

Length of plesiotype, 1.02 mm., height 0.57 mm., width 1.0 mm.

Bosquet's original figures of this species are somewhat misleading. The anterior end, as shown in the figures, appears narrower and more obliquely rounded, and the dorsal margin more nearly straight than it actually is. The writer has secured specimens of *B. alata* from Bosquet's type locality, the Maestrichtian chalk, from Maestricht, Holland, through the courtesy of Dr. J. H. Bonnema, of the University of Groningen. These specimens have a somewhat heavier and larger shell than those from the Navarro clays of Texas, but are otherwise so closely similar that the writer does not feel that even varietal distinction should be made. The thickness of the test is probably a purely environmental factor.

Occurrence.—*B. alata* occurs in the Navarro, and in some outcrops of upper Taylor clays. It is a rare form

at most localities where it appears, but is fairly common at a few Navarro localities. In Arkansas, it appears as a rare form in the Saratoga chalk.

Plesiotype.—No. 0–2419.2 Alexander Collections, collected at Station No. 2491.

Genus CYTHEREIS Jones, 1849

Species of the genus *Cythereis* exhibit, perhaps, greater variation in form and in surface ornamentation than those belonging to any other genus of the Ostracoda. Among the highly varied assemblage of species assignable to this genus are forms with strongly developed alaeform lateral expansions at the ventral edge of the shell. These alate species of *Cythereis* bear a remarkably close resemblance to the winged species of the genus *Brachycythere*, described above. The winglike ventral expansions of the shell have been developed in so many genera of the family Cytheridae, however, that their presence cannot be regarded as of much significance in determining generic relationships. As has been the case with the alate representatives of other genera, these species of *Cythereis* have been referred by some authors to the genus *Cytheropteron*.

The fact that no genotype has, as yet, been named for the genus *Cythereis* makes an outline of the generic characters a somewhat difficult problem. It is not the purpose of the writer at the present time, to discuss the shell characters of *Cythereis* in detail. Only certain significant characters which seem to be shared by typical representatives of the genus, will be pointed out and discussed. Specimens of *Cythereis ornatissima* (Reuss) have been selected for the preparation of the figures illustrating the shell structures of the genus (pl. 25, fig 18; pl. 26, figs 11*a*, *b;* pl. 27, figs. 16*a*, *b*). This species, in the writer's opinion, exhibits most of the significant characters of the genus *Cythereis*, in typical form, and is generally recognized as a characteristic representative of the genus. Jones listed this species, under the name *Cythereis ciliata* (Reuss), in the pages following his original description of the genus,[19] and later lists *C. ciliata* as a synonym of *C. ornatissima*.[20]

The carapace in *Cythereis* is highest at the anterior end, with a more or less abrupt downward curve or slope immediately behind the high, rounded, antero-dorsal angle. With the exception of this down-curve at the anterior end, the hinge margin is straight. The left valve is larger than the right, but overlaps it conspicuously only at the high, antero-dorsal angle. The ventral margin is also straight, or nearly so, and it and the dorsal margin are subparallel, converging but slightly toward the posterior end. The anterior end is broadly rounded, denticulate along the lower one-half or two-thirds of its length, and in most species bears

[19] Jones, T. R., Monograph of the Cretaceous Entomostraca of England: *Monogr. Paleontogr. Soc. London*, p. 19, pl. 4, figs. 11*a–h*, 1849.

[20] Jones, T. R., and Hinde, G. J., A supplementary monograph of the Cretaceous Entomostraca of England and Ireland: *Paleontogr. Soc. London*, p. 21, pl. 2, figs. 1–7, 15, 16, pl. 4, figs. 7, 8, 1890.

a more or less strongly thickened and elevated rim. The posterior end is strongly compressed, and is characteristically more or less distinctly triangular in shape, being obliquely truncated above, and rounded and denticulate below. The posterior end, like the anterior, bears, in most species, a thickened marginal rim. In most species the carapace is widest at the ventral margin, with the ventral surface flat, and forming right or more or less acute angles with the lateral surfaces of the valves (pl. 27, fig. 16*b*). The dorsal surface of the carapace, while much narrower than the ventral, is also flat, and in most members of the genus, increases gradually in width toward the posterior end. A transverse section of the carapace has a roughly quadrate form (pl. 25, fig. 16*a;* pl. 27, figs. 16*b*).

Jones evidently regarded the subcentral tubercle, a more or less strongly elevated, rounded tubercle found near the center of the valves of many species of *Cythereis* as a character of primary importance in differentiating the genus. In his original description of the shell characters of the genus, he refers to it as "very characteristic of this section,"[21] and on an earlier page of the monograph in which this description appears, he states that "In *Cythereis* a large external tubercle is always present at the central line in the anterior third of each valve . . . ."[22] This subcentral tubercle, however, is obscured by a median longitudinal fold or ridge in *Cythereis triplicata* (Roemer) and in numerous similar forms. The alate members of the genus, also, have smooth valve surfaces, without any indication of a subcentral tubercle. Yet, Jones assigns species of both types to *Cythereis*, in the appendix to his monograph.[23]

The most important character of all in establishing a species as a member of the genus *Cythereis* is the hinge structure (pl. 26, figs. 11*a*, *b*). This consists, in the right valve, of a strong, knob-like anterior tooth and a posterior tooth which in most species is either rounded and knob-like or only slightly elongated and compressed. In a few species the posterior tooth has the form of a serrate ridge, like that of *Brachycythere*. Immediately behind the anterior tooth is a deep socket. The hinge margin of the right valve, between this socket and the posterior tooth, bears a shallow groove, above which the dorsal edge of the valve projects slightly as a low, narrow ridge or bar. Corresponding to the anterior tooth and postjacent socket of the right valve, the hinge margin of the left valve bears a deep anterior socket, and immediately behind it, a strong, knob-like tooth. This tooth lies below, but is attached to the dorsal edge of the valve, which, between this tooth and the socket at the posterior end of the hinge line, is elevated to form a high, narrow, bar or ridge. *There is no bar below and distinct from the dorsal edge of the valve itself.* The hinge structure of *Cythereis* differs thus most markedly from that of *Brachycythere*.

[21] Jones, T. R., *op. cit.*, p. 15.
[22] Jones, T. R., *op. cit.*, p. 8.
[23] Jones, T. R., *op. cit.*, p. 35, 36.

CYTHEREIS ORNATISSIMA (Reuss)

Plate 25, figure 18; plate 26, figures 11*a*, *b*; plate 27, figures 16*a*, *b*

Cytherina ornatissima REUSS, *1846*, Verstein. bohm. Kreidef., pt. 2, p. 104, pl. 24, figs. 12, 18.

Cytherina ciliata REUSS, *ibid.*, fig. 17.

Cytherina echinulata WILLIAMSON, *1847*, Trans. Manchester Lit. Phil. Soc., vol. 8, pl. 4, figs. 75, 76.

Cythereis ciliata JONES, *1849*; Monogr. Cret. Entom. Eng., Paleontogr. Soc. London, p. 19, pl. 4, figs. 11*a–h*.

Cypridina muricata REUSS, *1851*, Haidinger's Nat. Abhandl., vol. 4, pt. 1, p. 50, pl. 5, figs. 12*a–c*.

Cythere ornatissima BOSQUET, *1854*, Mém. Comm. Carte géol. Neerlande, vol. 2, pp. 107–110, pl. 9, figs. 6*a–d*.

Cythere (*Cythereis*) *ornatissima* WILLIAMSON, *1872*, Trans. Lit. Phil. Soc. Manchester, ser. 3, vol. 5, p. 136.

Cythereis ornatissima CHAPMAN, *1917*, Geol. Survey western Australia, Bull. 72, p. 55, pl. 14, fig. 10.

Cythereis dallasensis ALEXANDER, *1929*, Univ. Texas, Bull., 2907, p. 99, pl. 8, figs. 8, 9.

Carapace oblong, subquadrate, highest in front. Dorsal and ventral margins straight, converging slightly posteriorly. Anterior end rounded, rimmed, denticulate. Posterior end compressed, triangular in outline, with raised marginal rim and numerous short, spine-like teeth along lower border. A rounded subcentral tubercle bears a cluster of strong, needle-like spines. Entire surface of valves covered with short, spinose processes, which are most numerous and most strongly developed around the borders of the valves. The bases of the spines are connected by low ridges, which thus form a reticulate pattern.

Length of plesiotype figured on Plate 25, fig. 18 and Plate 27, figs. 16*a*, *b*, 0.9 mm., height 0.48 mm., width 0.47 mm.

This species exhibits some variation in the surface marking and especially in the relative strength of the spinose processes and the reticular ridges which connect the bases of these processes over the lateral surface of the valves. In the form described by Alexander as *Cythereis dallasensis*, the reticulation is the most prominent feature of the ornamentation, and the spinose processes are short and relatively inconspicuous. Examination of a large number of specimens has indicated that every graduation occurs between this, and the more typical form herein illustrated, in which the spines are strongly developed and conspicuous, and the reticulation obscure. It is, therefore, the writer's opinion that in spite of the variation, these forms properly constitute a single species.

The writer has recently had the opportunity, through the courtesy of Doctor Joseph A. Cushman, of examining specimens of *C. ornatissima* from the type locality, an exposure of the Turonian "Planer-marl" at Luschitz, Bohemia. The specimens are a part of a small collection of Ostracoda from the Cretaceous of Bohemia identified by Reuss himself, and now in the Museum of Harvard University.

Occurrence.—*C. ornatissima* occurs abundantly in the upper Austin chalk in all parts of the state, and in the Gober chalk in northeast Texas. It is fairly common in the Brownstown marl, which underlies the Gober in the northeast Texas section, but is rare in the corresponding lower Taylor clays and marls in other parts of the state. The form described as *C. ornatissima* by Alexander, from the

Lower Cretaceous of Texas,[24] exhibits no trace of reticulation on the surface, and differs in other important respects, and should be regarded as a separate species.

Plesiotypes.—No. 0–2410.5 Alexander Collections, collected at Station No. 24124.

CYTHEREIS PUSTULOSISSIMA, Alexander, new name

Cythereis ornatissima ALEXANDER (not *C. ornatissima* Reuss, 1849), *1927*, Univ. Texas Bull. 2907, p. 95, pl. 10, figs. 10, 15.

This new name is herewith proposed for the species previously described by the writer as *C. ornatissima*.

C. pustulosissima is a very common and characteristic species of the Washita division of the Lower Cretaceous of Texas.

CYTHEREIS THOMASI Israelsky, new name

Plate 25, figures 16*a*, *b*; plate 27, figure 17

Cytheropteron ponderosana ISRAELSKY, *1929*, Ark. Geol. Survey, Bull. 2, p. 9, pl. 2A, figs. 1*a–c*.

Carapace in side view elongate, quadrate in outline, highest at anterior end. Dorsal margin straight except for slight downward slope just behind high, anterior end. Ventral margin straight. Dorsal and ventral margins subparallel, converging slightly posteriorly. Anterior end broadly and slightly obliquely rounded, with thickened, rounded marginal rim, and bearing numerous long, strong, spine-like teeth along the lower two-thirds of its margin. Posterior end broadly rounded below, obliquely truncated above; curved lower border bears five or six teeth similar to those at the anterior end. Postero-dorsal angle of left valve bears a short, blunt, posteriorly and dorsally projecting spine. This spine, as well as many of the marginal teeth, is broken off in most specimens, but its broken base can be recognized. The anterior portion of the carapace is compressed. The carapace widens gradually posteriorly, and attains its greatest width at the ventral margin, directly below the posterior end of the hinge line and just in front of the compressed posterior end. The ventral edge of each valve bears a strong, compressed, wing-like lateral expansion. In dorsal view the carapace is broadly sagittate in outline. The outer border of each wing is straight in its anterior half, but becomes gently curved and convex posteriorly, terminating at the postero-lateral angle in a short, sharp, slightly curved, horn-like spine; the posterior border is concave. The anterior marginal rim of the shell continues backward as the outer border of the wing. There is a narrow, flat area along the posterior one-half of the dorsal margin of the shell, bounded laterally by a low, rounded ridge which arises a short distance behind the anterior cardinal tubercle on each valve, runs backward along the outer edge of the flattened dorsal area, and terminates at the posterior end of the hinge line. The anterior marginal rim of the carapace is continued backward along the dorsal margin for a short distance, but terminates near the anterior end of the low, longitudinal ridge described above.

[24] Alexander, C. I., Ostracoda of the Cretaceous of North Texas: *Univ. Texas, Bull.* 2907. p. 95, pl. 10, figs. 10, 13, 1929.

Length of plesiotype, 0.95 mm., height 0.5 mm., width 0.8 mm.

On a later page of the same paper in which Israelsky published the original description of this species, under the name *Cytheropteron ponderosana*, he described another species under the name *Cythereis ponderosana*.[25] This latter form was recognized by the present writer, and erroneously assigned to the genus *Cythere* in his "Ostracoda of the Cretaceous of North Texas."[26] Subsequent consideration of the shell characters indicates that Israelsky's original generic assignment was correct.

Mr. Israelsky has recently given the writer representatives of most of his species from the Upper Cretaceous of Arkansas. The writer finds that the forms described by Israelsky under the names *Cythereis ozanana*, and *C. ponderosana* are specifically identical. The slight differences pointed out in the original descriptions are doubtless sexual differences. The two forms have exactly the same stratigraphic ranges in the Texas Cretaceous. The name *C. ozanana* must be recognized for this species, as it appears above *C. ponderosana*. In spite of the fact that the name *Cythereis ponderosana* Israelsky must be suppressed as a synonym for *C. ozanana* Israelsky, the name *Cythereis ponderosana* (Israelsky) cannot be recognized for the alate species originally described as *Cytheropteron ponderosana*. The writer has asked Mr. Israelsky to suggest a new name for this species, and, under date of November 25th, 1932, he has selected the name *Cythereis thomasi*, under which name this species is herewith described.

Occurrence.—Israelsky records the species as occurring through the Ozan, Annona and Marlbrook formations of Arkansas. In the writer's collections from the Upper Cretaceous of Texas, it appears only in the Annona chalk of the northeast Texas section. Several species similar to this occur in the Upper Cretaceous formations in Texas, but are readily differentiated by critical observation.

Plesiotype.—No. 0–2472.2 Alexander Collections, collected at Station No. 24115.

DESCRIPTION OF OUTCROPS

Station No. 2302.—Upper Goodland limestone and marl are exposed in a road cut which truncates three small, rounded spurs known as "Cragin's Knobs," three miles west of the Texas and Pacific Railroad shops in Fort Worth, on the Stove Foundry Road. The marl layers yield a rich microfauna, and this exposure is the type locality for *Cytheropteron* (*Cytheropteron*) *bicornutum* n. sp., *Cytheropteron* (*Eocytheropteron*) *howelli* Alexander, *C.* (*E.*) *pirum* n. sp., and *C.* (*E.*) *paenorbiculatum* n. sp. This exposure has also been named as type locality for five other species of Ostracoda (Univ. Texas, Bull. 2907, Station No. 2, p. 17, and Am. Midland Naturalist, vol. 13, no. 5, pp. 308–309), and for several species of Foraminifera (Contrib. Cushman Lab. Foram. Research, vol. 6, no. 1).

Station No. 2305.—The entire 35 feet of the Kiamichi formation, consisting of dark, finely laminated clay, is exposed in a deep road cut just north of the Texas and Pacific Railroad shops, Fort Worth. This exposure is

[25] Israelsky, M. C., Upper Cretaceous Ostracoda of Arkansas, *Ark. Geol. Survey, Bull.* 2, p. 13, pl. 3A, figs. 5–8, 1929.

[26] Alexander, C. I., Ostracoda of the Cretaceous of North Texas, *Univ. Texas, Bull.* 2907, p. 83, pl. 6, fig. 3, 1929.

the type locality for *Cytheropteron* (*Eocytheropteron*) *tumidum* Alexander, and for *C.* (*E.*) *semiconstrictum* n. sp. The outcrop has previously been named as type locality for other species of Ostracoda, and plesiotypes of species originally described from the Lower Cretaceous of Europe have been figured from this locality. (See Univ. Texas, Bull. 2907, Station No. 5, p. 20.)

Station No. 2325.—Yellowish and brownish clays of the basal portion of the Weno formation are exposed in the bank of a small gully which flows northward to empty into a tributary of Sycamore Creek, about ¼ mile below (east of) the point where the stream has been dammed to form a small lake, known as "Katy Lake," south of Forth Worth. The clays from this locality yield the richest and best preserved samples of microfossils found in the entire Lower Cretaceous of Texas. The outcrop has been selected as type locality for *Cytheropteron* (*Cytheropteron*) *wenoense* n. sp., and has previously been named as type locality for two other species of Ostracoda, one of which, *C.* (*C.*) *rugosalatum* Alexander, is herewith described and figured. (See Univ. Texas, Bull. 2907, Station No. 25, p. 29.)

Station No. 2326.—Upper Weno limestones and marls, and the brownish, basal clays of the overlying Paw Paw formation are exposed in a roadside ditch, along the west side of the graveled road which leads from the old Fort Worth-Burleson highway to the town of Everman, about ¼ mile southeast of the intersection of the two roads, and about 400 feet south of a bridge where the Everman road crosses a small stream. From the basal Paw Paw clays at this locality, *Cytheropteron* (*Cytheropteron*) *acutolatum*, and other Ostracoda have been described. (See Univ. Texas, Bull. 2907, Station No. 26, p. 28.)

Station No. 2329.—Dark, blue-black, finely laminated shales of the Weno formation are exposed in a deep railroad cut on the Missouri, Kansas and Texas Railroad, about 1 mile northeast of Denison, Texas. This is the type locality for *Cytheropteron* (*Eocytheropteron*) *bilobatum* Alexander, which has been named type species of the subgenus *Eocytheropteron*.

Station No. 2361.—Del Rio clays are exposed in a conspicuous, conical outlier near the road to the Mexican cemetery south of the city of Del Rio. This exposure is the type locality for *Cytheropteron* (*Eocytheropteron*) *delrioense* n. sp., and tests of the large foraminiferan *Haplostiche texana* (Conrad) have been figured from this locality. (See Univ. Texas, Bull. 3101, Station No. 232-T-6, p. 123.)

Station No. 2434.—Lower Taylor clays, about 100 to 150 feet above the top of the Austin chalk, are exposed in a gully north of the Austin-Manor highway, at the east end of a long bridge over Walnut Creek, about 6 miles east-northeast of the University of Texas campus. This is the type locality for *Cytheropteron* (*Cytheropteron*) *furcalatum* n. sp., and has previously been named as type locality for the foraminiferan *Kyphopyxa christneri* (Carsey). (See Univ. Texas, Bull. 3101, Station No. 226-T-7, p. 121.)

Station No. 2438.—The zone of *Metoiceras whitei* Hyatt, in the Eagle Ford formation, is exposed in a high, steep bluff on the west bank of Indian Creek, at a point about 6½ miles east of the railroad crossing at Lewisville. This is the type of locality for *Cytheropteron* (*Cytheropteron*) *eximium* n. sp.

Station No. 2460.—Lower Navarro clays are exposed in a large, abandoned clay pit of the Corsicana Brick Company, two miles south of Corsicana. Plesiotypes of *Cytheropteron* (*Cytheropteron*) *navarroense* Alexander, *Orthonotacythere hannai* (Israelsky), and *Brachycythere ledaforma* (Israelsky) figured in this paper were collected at this locality. This is the type locality for *Cytheropteron* (*Cytheropteron*) *navarroense*, and for seven other species of Ostracoda (Univ. Texas, Bull. 2907, Station No. 60, p. 46), as well as for five species of foraminifera (Univ. Texas, Bull. 3101, Station No. 174-T-4, p. 119).

Station No. 2491.—Lower Navarro clays are exposed in a high, steep slope on the bank of Onion Creek just east of the bridge at Jones' Crossing on the Austin-Bastrop highway. Concentrates from these clays are rich in beautifully preserved specimens of both Ostracoda and foraminifera. The plesiotypes of *Brachycythere alata* (Bosquet) figured in this paper were collected here. The exposure has also yielded plesiotypes of several species of foraminifera, and is the type locality for

several others. (Univ. Texas, Bull. 3101, Station No. 226-T-9, p. 121.)

Station No. 24113.—Lower Brownstown marl is exposed in a roadside ditch at the north end of a small concrete culvert, 1.85 miles southeast of Bagwells on the Paris-Clarksville highway. Plesiotypes of *Brachycythere sphenoides* (Reuss) were collected at this locality.

Station No. 24115.—Lower Annona chalk is exposed in a deep roadside ditch west of the White Rock road, 0.75 mile north of the point where this road turns northward from the Paris-Texarkana highway, 6.95 miles east of the courthouse in Clarksville. This is the type locality for *Cytheropteron* (*Cytheropteron*) *blakei* n. sp., and plesiotypes of *Orthonotacythere pedata* (Marsson) and *Cythereis thomasi* Israelsky figured here, were also collected at this locality.

Station No. 24124.—Brownstown marl is exposed in a deep roadside ditch west of the Honey Grove-Monkstown road 4 miles north of the town square in Honey Grove. The plesiotype of *Brachycythere sphenoides* (Reuss) used to illustrate the muscle scar pattern of the genus, and the plesiotypes of *Cythereis ornatissima* (Reuss) figured here were collected at this locality.

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A MICRO-FOSSILIFEROUS UPPER CRETACEOUS SECTION FROM SOUTH DAKOTA

E. R. APPLIN

During the years 1927 through 1930, the Cosden Oil Company drilled two wells in South Dakota from which complete sections were submitted for study. The results, both from a stratigraphic and micropaleontologic standpoint, were very interesting, and in view of the fact that no sections, studied in this manner have been published from that state, the author decided to write a paper covering the general stratigraphic and faunal features indicated.

The paper gives only a preliminary discussion of the subject, and is offered with the hope that it may throw light on the deposition and structural possibilities of the buried sections in the western part of the state. The wells to be discussed are located in the western central part of the state, and are known as the J. S. Cosden State School Lands No. 1, drilled in the center of sec. 16, T. 9 N., R. 17 E., Meade County; and the Ole Tanberg No. 1, put down in the NW. ¼, Sec. 9, T. 11 N., R. 12 E., Zieback County. The State School Lands well was completed in July, 1927, with a total depth of 2,970 feet. The Ole Tanberg No. 1, was completed in August, 1930, at a total depth of 3,604 feet in gypsum where the drill pipe twisted off and could not be fished out.

Some marked variations in formational thicknesses will be noted between the two wells, and with the standard outcrop sections. Some of this may be due to the fact that the major portion of the sample material consisted of cuttings, but the sections were practically continuous, the samples were carefully taken and a repeated study of the materials pursued at intervals over a period of several years has led to the conclusions herein given. Further drilling will probably reveal the cause for the differences shown.

The well known as the State School Lands No. 1 was drilled with cable tools and the samples were remarkably free from the mixing common to the materials found in rotary drilling samples.

DESCRIPTION OF THE SECTION SHOWN IN THE STATE SCHOOL LANDS NO. 1

UPPER CRETACEOUS, *Pierre Shale.*—444 feet (first sample) to 1,198 feet. The first sample submitted came from 444 feet, at which depth the well was apparently drilling in the Pierre shale formation. Between this depth and 1,198 feet, which we take as the bottom of the Pierre, the samples consisted mainly of soft gray shale which dissolves readily in water,

leaving, after the more floculent material is decanted off, a small residue composed of a few harder fragments of the shale (which turn brownish-gray in drying), a small amount of pyrite, *Inoceramus* fragments sometimes forming 25 per cent of the washed residue, and a few fragments of some nacreous shell (*Pteria?* sp.). Except for 25 feet, between 775 feet and 1,000 feet, forams are nearly always present. The fauna is never abundant either in numbers or species, but it is persistent and characteristic only of this formation in that area. At 575, 775, 875 and 1,100 feet the samples show a large percentage of fragments of hard (probably concretionary) limestone, varying somewhat in color and character at each depth listed. At 880 feet the sample was composed of light-gray ash which apparently occurred as a thin lens in the shale. Below 1,100 feet the shale is much darker in color than in the higher portions of the section.

Niobrara Formation.—1,198 feet to 1,720 feet. Between these depths the cuttings show large washed residues of fragments of the characteristic "speckled" shale alternating with hard, solid black, bituminous shales. The bituminous material first appeared between 1,150 and 1,198 feet, but I have chosen the first appearance of the "speckled" shale for marking the top of this formation as a more definite point for correlation purposes. The speckled appearance of much of the shale is due apparently to the presence of a considerable amount of finely disseminated, disintegrated shell and foram material. Shales, closely similar in character, suggesting similar depositional conditions occur as a thin but persistent lens in the base of the Eagle Ford formation of Texas, through the Niobrara of Nebraska sections, in the basal portion of the Selma Chalk formation of western Florida, and in thin lenses in the lower portion of the San Felipe formation of Mexico, and undoubtedly occurs in other regions with which the writer is not familiar. Pyrite is present but less abundant than in the Pierre. *Inoceramus* fragments are also occasionally noted. Forams occur abundantly in many of the "speckled" lenses. The fauna is quite distinct from that found in the Pierre, both in the character of the preservation and in the species. Specimens are numerous, but species very few. At 1,370 feet, what appears to be a thin lens of red-brown, highly ferruginous, cherty rock was indicated through the sample. A similar lens was found at the top of the formation in the Ole Tanberg No. 1, and will be mentioned again in that connection. Shales, as described above continue to form the entire sample content down to 1,720 feet giving an unusual thickness for this formation.

Carlile Shale.—1,720 to 2,015 feet. At 1,720 feet a marked change was noted in the samples. Between that depth and 2,015 feet the washed residues were small and the materials vary from finely sandy gray shales to very fine-grained, loosely consolidated, gray sandstones. Pyrite is more abundant than in either of the previously described formations, often forming 25 per cent of the washed residues. Thin lenses of carbonaceous, dark gray shale were occasionally noted. Forams were rare, both in species and occurrence. Arenaceous forms, only, appeared. In some instances the specimens were numerous, but even then only one or two species appeared. The fauna, however, is of value since it is quite distinct from those found in the two previously described formations.

Greenhorn Limestone.—2,015 feet to 2,331 feet. The samples from both wells suggest that the Greenhorn limestone changes in its buried characteristics from a solid bed of fossiliferous limestone to a series of interbedded black shales and thin, shaly, organic limestones. The drillers logs, as well as the samples, indicate such a condition. The limestone lenses are thin but numerous, and consist of a shell breccia composed mainly of small fragments of *Inoceramus* and a few fragments of other shells. Both the shale and the limestone layers are highly bituminous in character. Beds of this type begin at 2,015 feet in this well and continue to a depth of 2,331 feet. At 2,060 feet a thin bed of speckled shale, similar to that of the Niobara, appeared, but lighter in color than in that formation and showing, also, a large percentage of imbedded fish scales. No forams were found through the samples assigned to this formation. The drillers log ends this series at 2,310 feet, but these materials continue through the samples to 2,331 feet,

which is questionably placed as the base in this discussion.

Graneros Shale.—2,331 to 2,544 feet. The top of this formation was placed at the bottom of the last limestone lens indicated by the samples, and the beginning of a hard, solid black shale section which is followed below 2,415 feet by fine-grained dark-gray sands and sandy shales containing a small amount of mica and a little glauconite. There were no indications of fossils present.

Dakota Sandstone.—2,544 to 2,672 feet. At 2,544 feet a fine-grained, light-gray, well consolidated sandstone appears, carrying water. Below this depth the sands become steadily coarser and less well consolidated down to 2,600 feet where the sand is white, coarse-grained and unconsolidated and carries water estimated at 5,000 barrels a day. This continues to 2,672 feet. The sand is even-grained, subangular, clear quartz showing many crystal faces giving to it its characteristic glistening appearance. Except for the coarseness of the sand grains it closely resembles the Woodbine sand of Texas.

LOWER CRETACEOUS—*Fuson Shale.*—2,672 to 2,820 feet. Casing was set on a black bituminous shale at 2,672 feet and beds of this character continue to 2,729 feet where they are replaced by dark-gray, very fine-grained, highly pyritic and calcareous sandstones which also contain a small amount of glauconite and a few shell fragments. Following this, the section continues as a black shale down to 2,820 feet.

Lakota Sandstone.—2,820 feet to 2,970 feet (bottom of hole). At 2,820 feet sand and water again appear. The sand is light-gray in color and similar in character to that assigned to the Dakota formation, and as in that formation, the sand grains become steadily coarser with increasing depth down to 2,925 feet, where it is coarse, white and subangular. Between this depth and 2,970 feet the well was again drilling in black shale in which material the well was completed.

The Ole Tanberg No. 1 was drilled with rotary tools and more mixing of materials was, therefore, noted in the cutting samples from the upper part of the hole. However, the samples were practically continuous, and they were very carefully studied for the introduction of new materials. Also the distinctive character of the formations drilled through has helped me to make what I believe to be a fairly accurate series of formational divisions.

DESCRIPTION OF THE SECTION SHOWN IN THE OLE TANBERG NO. 1

UPPER CRETACEOUS—*Fox Hills Formation.*—40 (first sample) to 280 feet. The well at the first depth received was drilling in the lower portion of the Fox Hills formation. The samples covering the depths included in this formation show soft, sandy, gray and brownish-gray clay-shales containing a few nodules of oxidized glauconite, a very little pyrite and a few fragments of shell, apparently fresh water species. Below 200 feet many fragments of brown sandy limestone were present in the cuttings, and at 240 feet many fragments of carbonaceous material and many fragments of fibrous vein calcite were noted. No forams were found in this formation.

Pierre Shale.—280 feet to 1,360 feet. These depths apparently represent the thickness of the Pierre shale formation in this well. The upper part of the section, not included in the State School Lands samples, shows a small amount of ash (380–400 feet) and a few white spotted shales which apparently represent the so-called "ashy" shales of the upper part of the section on the outcrop. *Inoceramus* fragments were first noted at 860 feet. Concretions, or thin lenses of hard limestones, were indicated by the materials present in the samples from 1,100, 1,500, and 1,600 feet. Forams appear continuously throughout the section, few in numbers and in species, as in the first well discussed, and showing the same faunal characteristics. The general character of the materials found between the depths assigned to this formation was the same as in the State School Lands No. 1.

Niobara Formation.—1,640 to 1,840 feet.

At 1,640 feet a red-brown, highly ferruginous, granular non-calcareous rock occurs, which is questionably correlated with a rock of similar character found at 1,370 feet in the Meade County well. If this determination is correct, a little over 200 feet of beds are missing from the top of the section in this well. As in the first well, these beds are followed by the typical speckled shale section of that formation already described. Beds of this character continue to a depth of 1,840 feet.

Carlile Shale.—1,840 to 2,177 feet. Due to the resistant character of the shales, as well as the comparatively thin section of the Niobara, forams, which in the first well were confined to the Niobara, occur in samples from the Carlile in this well together with the typical species of the latter formation. The dissimilar character of the preservation, however, as well as the possibilities for mixing mentioned above would suggest that the grouping as given under the State School Lands well is most probably correct, although alternating depositional conditions might cause such a change in stratigraphic distribution, Lithologically, the character of the Carlile is in all respects like that covered by the description for this formation given in the discussion of the Meade County well.

Greenhorn Limestone.—2,177 to 2,380 feet. This formation also shows the same characteristics as indicated by the previous well. Pyrite is very abundant in this formation, often forming 50 per cent of the washed residues. The drillers log gives 2,365 feet as the apparent base of this section, but the limestone fragments continue to make up the major portion of the sample content down to 2,380 feet.

Granerous Shale.—2,380 to 2,745 feet. Beds assigned to this formation begin at 2,380 feet with the solid black shale, as in the Meade County well, and become more sandy, showing interculated beds of dark-gray, argillaceous, and slightly micaceous sands and sandy clays near the base. In this well the sandy phases are thinly streaked with a black tarry residue.

Dakota Sandstone.—The fine-grained, light-gray sandstones found in the State School Lands No. 1 appear to be missing in this well, and we include in this formation only the beds represented by cores from 2,745 to 2,765 feet, showing a coarse-grained, angular, clear quartz sand carrying no water.

LOWER CRETACEOUS—*Fuson Shale.*—2,769 to 2,971 feet. Between these depths the samples consist of cuttings, bit samples and cores showing a black bituminous shale containing a great deal of pyrite. This changes below 2,896 feet to a dark-gray, very fine-grained, well consolidated sandstone thickly streaked with a black asphaltic residue.

Lakota Sandstone.—2,971 to 3,039 feet. Below 2,896 feet the samples were all cores. At 2,971 feet the core shows an extremely fine-grained sandstone heavily streaked with the black asphaltic residue mentioned above. These sandstones persist and the tarry content increases down to 3,010 feet, where the sand is colored black from this material and an ether test gives a good oil show. Between this depth and the basal sandstone found at 3,027 to 3,031 feet, the sands are progressively coarser and the bituminous matter decreases to the point of total elimination at 3,020 feet. The basal sand is moderately coarse and even-grained, very light-gray in color. Pyrite is abundant in all the samples studied from this formation. No fossils were noted.

Morrison Formation.—3,039 to 3,220 feet. The cores which represent this part of the section are composed of light-gray green, argillaceous, slightly sandy, gritty, and usually non-calcareous clays, and cross-bedded, very fine-grained sandstones containing paper thin lenses of light-green shale. At 3,157 feet many casts of flattened, tubular bodies, resembling plant stems, were noted.

JURASSIC—*Sundance Formation.*—3,220 feet to 3,505 feet. The break between the Morrison and the Sundance is not clearly marked. I have rather arbitrarily chosen 3,220 feet, the top of the solid, dark-green shale section, as the point of contact. These shales are dark-green, unctuous, and flaky in character and occasionally show fragments of shell material. At 3,287 feet, a brownish-red, hard, sandy, calcareous clay appears, but at 3,358 feet the green shales again return to the section. At 3,391 feet a little black shale and some extremly fine-grained, hard, calcareous sandstone comes in. Between this depth and 3,430 feet the cores are composed of light-gray,

compact, highly calcareous, very fine-grained sandstones, occasionally showing fragments of shell material. At 3,430 feet there is a core of dark reddish-brown, hard, calcareous and slightly sandy shale, and at 3,483 feet to 3,485 feet a core of highly indurated pink limestone was taken. These red beds I believe to be the equivalent, at least in part, of the basal red sandstones often forming the lower limits of the formation on the outcrop.

TRIASSIC (?)—*Spearfish Formation.*—3,505 to 3,581 feet (bottom of the hole). At 3,505 feet we find the first non-calcareous red shales and assign these beds to the Spearfish formation. These shales are finely sandy and in places highly micaceous as well. They continue to 3,575 to 3,581 feet, where the hole was lost, and the core taken shows a bed of sold red gypsum.

SPECIES OF FORAMINIFERA

Grouped for relative abundance in descending order.

State School Lands No. 1

Pierre Shale

Ammodiscus glabratus Cushman and Jarvis.
Trochammina sp.?
Buliminella carseyae Plummer.

Gaudryina filliformis Berthelin.
Anomalina involuta (Reuss)
Gyroidina micheliniana d'Orbigny.

Bulimina obtusa d'Orbigny.
Quinqueloculina cf. *circularis* Bornemenn
Glomospira charoides var. *corona* Cushman and Jarvis.
Gyroidina depressa (Alth).
Ceratobulimina cretacea Cushman and Harris.
Globigerinella aspera (Ehrenberg)

Hyperammina(?) sp.(?)
Robulus megalapolitana (Reuss)
Robulus macrodiscus (Reuss)
Marginulina jonesi Reuss.
Globigerina cretacea d'Orbigny.

Niobara Formation

Globigerina cretacea d'Orbigny.
Gümbelina globulosa (Ehrenberg).

Carlile Shale

Haplophragmoides glabra Cushman and Waters.
Haplophragmoides cf. *gigas* Cushman.

Ole Tanberg No. 1

Pierre Shale

Bulimina obtusa d'Orbigny.
Trochamina sp.?
Robulus macrodiscus (Reuss)
Ammodiscus glabratus Cushman and Jarvis
Gaudryina filiformis Berthelin.
Epistomina caracolla Reuss.

Hyperammina? sp.?
Pelosina complanata Franke
Glomospira charoides Parker and Jones, var. *corona* Cushman and Jarvis.
Gyroidina depressa (Alth).
Buliminella carseyae Plummer.
Anomalina involuta (Reuss)
Silocosigmoilina californica Cushman and Jarvis.
Robulus megalopolitana (Reuss)
Marginulina jonesei Reuss.
Spiroplectammina anceps (Reuss)
Bolivina incrassata Reuss
Gaudryina rugosa d'Orbigny.
Gümbelina globulosa (Ehrenberg)
Gümbelina globulifera (Ehrenberg)
Nodosaria distans Reuss.
Haplophragmoides rugosa Cushman and Waters.
Cribrostomoides trinitatensis Cushman and Jarvis.
Robulus navarroensis (Plummer)

Carlile Shale

Gümbelina globulifera (Ehrenberg)
Globigerina cretacea d'Orbigny.
Haplophragmoides excavata Cushman and Waters.
Haplophragmoides gigas Cushman.

DISCUSSION OF FAUNAS

The species lists given above should demonstrate the marked difference in aspect between the fauna of the Pierre, as found in these well sections and that of its supposed

equivalents, the Taylor Marl and the Papagallos, of more southern areas. Species which dominate the Taylor, as *Clavulina insignis* Plummer, *Globotruncata fornicata* Plummer, *Globetruncata arca* (Cushman), *Astrocolus taylorensis* Plummer, *Planulina taylorensis* (Carsey), and *Dentalina alternata* (Jones), are not even represented in the Pierre. There is also an unusual combination of some species hitherto found only in high Cretaceous beds with typical Taylor species. In this regard, Dr. Cushman writes:[1]

> The samples from South Dakota referred to the Pierre have some rather interesting relationships. They contain species, such as *Glomospira charoides* var. *corona*, which are characteristic of the uppermost Cretaceous of Trinidad, and occur in the Velasco shale of Mexico. On the other hand, some of the samples contain *Buliminella carseyae* Plummer, and *Gyroidina michelina* d'Orbigny which are characteristic species of the Taylor as developed in Texas. On the whole, the uppermost portion referred to the Pierre has a number of forms which appear to be more like the Navarro than the Taylor, but the lower specimens closely resemble the typical Taylor. It may be noted that the conditions of deposition of the Velasco shale of Mexico and the Upper Cretaceous of Trinidad indicate comparatively deep water, more so than the typical Taylor marl of Texas. Other species such as *Marginulina jonesi* are also interesting, this species in America being known from the Upper Cretaceous of California, and from Trinidad. There are a few specimens of the Silicinidae, which resemble very much those described from the Upper Cretaceous of California, and which are known also from the Upper Cretaceous of western Canada. These are also closely related to *Rzehakina*, which again is characteristic of the Upper Cretaceous of Trinidad and the Velasco shale of Mexico. In the sample from 1,040 to 1,080 feet from the State School Lands No. 1, a species of *Ceratobulimina* occurs in combination with definitely Taylor species. In the general Gulf Coast section, however, *Ceratobulimina*, so far as I have seen, occurs only at the top of the Navarro. There are other discrepancies also that must be taken into consideration, but I do not know how to explain them as we know so little about the faunas from this part of the country.

[1] Letter to the author, dated March 18. 1932.

It must be borne in mind, also, that no fauna was found in beds younger than the Pierre, so that there is no question of species having come down the hole from younger and higher horizons.

The Niobara and Carlile, although they contain fewer species than their southern representatives, do not differ from them so markedly in their faunal characteristics.

The writer wishes to acknowledge her very great indetedness to Dr. Joseph A. Cushman for carefully listing the species, all of which were sent to him and are on file in his laboratory, and for contributing the paragraph on the discussion of the fauna, quoted above.

SOCIETY RECORDS AND ACTIVITIES

SEVENTH ANNUAL MEETING OF THE SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS

President, G. D. Hanna in the chair
Vice President, James A. Waters
Secretary-Treasurer, Gayle Scott
Editor, Raymond C. Moore

The seventh annual meeting of the Society of Economic Paleontologists and Mineralogists was held in the Rice Hotel at Houston, Texas, Friday, March 24, 1933. The meeting was in conjunction with the regular annual meeting of the American Association of Petroleum Geologists, also held at the Rice Hotel, March 23, 24, and 25, 1933.

The morning session of the meeting was called at nine o'clock, and papers 1–15 in the appended list were presented. The morning session was adjourned at twelve o'clock.

The afternoon session was called at two o'clock, and papers 16–25 were presented. The presentation of papers was completed at four o'clock, and after a recess of ten minutes, the business meeting was called. The following items of business were considered by the Society, in the order listed.

1. President Hanna suggested that since the minutes of the previous meeting had been published in the Journal of Paleontology, and were therefore available to all members of the Society, that they be accepted as published, unless there were objections from the floor. There were no objections.

2. The President and the Editor made their annual reports.

(*a*) President Hanna, in his report, presented the recommendations made by the Council of the Society of Economic Paleontologists and Mineralogists, at a meeting held the previous day, March 23rd, 1933. The Council voted to continue the publication of the Journal of Sedimentary Petrology during 1933, and authorized the Editor to appoint an Associate Editor to assume charge, under direction of the Editor, of this Journal. It was the belief of the Council that the cost of publication of the Journal of Sedimentary Petrology should be held very close to the amount received from sales and subscriptions for the Journal.

The Council adopted the policy of inviting all past-presidents of the Society in attendance at the annual meetings to sit at all council meetings, without, however, extending the power to vote to any of these former officials. The Secretary was instructed to send notices of this action to all past-presidents of the Society.

The Council voted to ask this meeting to approve or disapprove the submission of a mail ballot to the membership of the Society of Economic Paleontologists and Mineralogists relating to further negotiations for joint publication of the Journal of Paleontology with the Paleontological Society. The proposed plans for joint publication were outlined by the Editor in his report.

(*b*) The Editor stated that he and the Secretary-Treasurer had labored to improve the quality of the Journal of Paleontology, and to secure the maximum of returns for the money invested. He pointed to important savings in cost of printing, made through a more advantageous contract and the adoption of a new page style, and through a better contract for the production of plates.

He noted a marked tendency among papers submitted toward an increase in size and in number of plates, and suggested that it might be necessary for the Council to adopt a policy as to the length of papers and the number of plates allowed papers accepted for publication. He also suggested that a better arrangement of figures would often make possible a substantial reduction in the number of plates.

He stated that there were papers on hand dated from January, 1932, and that unless some method of increasing the size

of the Journal could be found, the accumulation of unpublished manuscripts would continue to grow. He suggested joint publication of the Journal of Paleontology with the Paleontological Society as a means of increasing the size of the Journal.

The proposed plan for joint publication voted by the Society last year was submitted to the Council of the Paleontological Society at their annual meeting in Boston in December, 1932, and was rejected. The Council favored joint publication, however, if an equitable arrangement could be made.

The Editor then reported two possible plans for joint publication suggested by the Council: (1) that the two societies publish alternate numbers of the Journal of Paleontology, retaining the present format, each society paying all costs of publications for their numbers, and distributing the Journal to all members of both societies, and (2) that both societies disband, and reorganize under a new name. He pointed out that under the first of these two plans, the size of the Journal could be considerably increased at no additional cost to members of the Society, and since many members of the Society of Economic Paleontologists and Mineralogists were also members of the Paleontological Society of America, some of their papers could be published in the numbers edited by the latter organization, thus, in two ways, reducing the accumulating list of unpublished manuscripts.

In the discussion following this report, Stephenson asked what arrangement would be made, under the first of the two proposed plans, for editing the numbers published by the two societies. Moore replied that although definite arrangement would have to be made if the proposal was accepted by both societies, it was probable that each society would elect its own editor who would edit the numbers published by that society.

3. The President at this point called for the report of the committee on joint publication, M. A. Hanna, chairman, F. B. Plummer, N. L. Thomas, Maynard White, Charles Ryniker. The chairman reported that the plan voted by the Society by mail ballot last year was submitted to the Paleontological Society at their annual meeting in Boston in December, 1932, and was rejected. The Council of the Paleontological Society, however, suggested the committees on joint publication of the two societies continue their negotiations in an attempt to reach an equitable arrangement.

Moore moved that the meeting approve or disapprove by its vote the submission of a mail ballot to the entire membership of the Society of Economic Paleontologists and Mineralogists, providing opportunity for vote on the following proposals: (*a*) to submit to the Paleontological Society the plan for publication of alternate numbers of the Journal of Paleontology by the Society of Economic Paleontologists and Mineralogists and the Paleontological Society, (*b*) to submit to the Paleontological Society the proposal to reorganize the two societies under a new name, (*c*) to submit both of the above proposals to the Paleontological Society and (*d*) to drop further negotiations for joint publication. Howe seconded the motion. Carried.

4. The report of the Secretary-Treasurer was read by C. I. Alexander, appointed acting secretary in the absence of Scott. The report was approved. The President suggested that since the Secretary had had a certified public accountant make an audit of the books, that the appointment of an auditing committee be eliminated, unless there were objections from the floor. There were no objections.

5. The Council proposed the name of Dr. Junius Henderson for honorary membership. It was moved by Johnson and seconded by Howe that Doctor Henderson be elected an honorary member of the Society. Carried unanimously.

6. The recommendation made by the Tulsa Stratigraphical Society that divisional editors for the Journal of Paleontol-

ogy be provided by the Society of Economic Paleontologists and Mineralogists, was outlined and discussed. The recommendation was dropped.

7. The president then called attention to the necessity for the naming of two divisional representatives to represent the Society of Economic Paleontologists and Mineralogists in the meeting of the Council of the A. A. P. G., at the 1934 meeting of the Council. It was moved by M. A. Hanna that the President of the Society be authorized to appoint the two representatives when the location of the 1934 meeting had been determined. Motion seconded by Adams. Carried.

8. The Secretary announced the results of the mail ballot for the nomination of officers for the ensuing year. The nominations were as follows:

For President: F. B. Plummer and James A. Waters.

For Vice President: H. G. Schenck and N. L. Thomas.

For Secretary-Treasurer: Gayle Scott, H. D. Norton and H. V. Howe.

For editor: R. C. Moore and Joseph A. Cushman.

The president then called for nominations from the floor. There were no further nominations.

9. The president appointed a committee consisting of Johnson, Harris and Fritz to collect and count the ballots for election of officers. Johnson announced the election of the following officers for the ensuing year:

President, F. B. Plummer
Vice President, H. G. Schenck
Secretary-Treasurer, Gayle Scott
Editor, Raymond C. Moore

10. Moore announced that the Division of Geology and Geography was being reorganized, and suggested that the Society of Economic Paleontologists and Mineralogists should be represented on this Division. Decker moved that the President be instructed to approach the National Research Council with the proposal that a representative from the Society of Economic Paleontologists and Mineralogists be included in the membership of the Division on Geology and Geography of the National Research Council. Adams seconded the motion. Carried.

11. The meeting was adjourned at six o'clock.

The following papers were presented at the technical session of the Society:

1. "Reversal of Valve Size and Hinge Structure in Species of Genus *Cytheridea*." C. I. Alexander and C. W. Alexander, Fort Worth, Texas.
2. "Apertural Characteristics of Genus *Hantkenina* with Description of New Species." H. V. Howe and Wm. E. Wallace, Baton Rouge, Louisiana.
3. "Geologic History of Lime-Secreting Algae." J. Harlan Johnson, Golden, Colorado.
4. "Insoluble Residues as Criteria for Pre-Pennsylvanian Correlation in Oklahoma." H. A. Ireland.
5. "Graptolites of Viola Limestone." Rudolf Ruedemann and Charles E. Decker, Norman, Oklahoma.
6. "*Bainbridgia typicalis*, New Genus of Silurian Auloporidae." John R. Ball, Evanston, Illinois.
7. "New Species Fayetteville Ostracoda from Washington County, Arkansas." R. W. Harris, Norman, Oklahoma.
8. "Paleontological Notes Concerning Savanna Formation in McAlester Quadrangle, Oklahoma." R. V. Hollingsworth, Norman, Oklahoma.
9. "Significant Micro-Fauna from Boggy Formation of Oklahoma." C. L. Cooksey, Norman, Oklahoma.
10. "Notes on New Occurrence of *Petrodus*." Dan J. Jones and J. Willis Stovall.
11. "Fossil Algae from Carboniferous of Central Colorado." J. Harlan Johnson, Golden, Colorado.
12. "*Glansoceras*, New Carboniferous Actinoceroid." Wm. B. Kramer, III, Ballinger, Texas.
13. "Foraminifera from Jurassic of Montana." John R. Sandidge, Princeton, New Jersey.
14. "New Species Foraminifera and Ostra-

coda from Duck Creek and Forth Worth of Southeastern Oklahoma." G. M. Harris.

15. "Zone of *Exogyra cancellata* traced 2,500 miles." L. W. Stephenson, Washington, D. C.
16. "Shell Structure of Ostracode Genus *Cytheropteron* and Fossil Species from Cretaceous of Texas." C. I. Alexander, Fort Worth, Texas.
17. "New Ammonite Fauna from Mexican Turonian." W. S. Adkins, Austin, Texas.
18. "Foraminifera and Ostracoda in Section of Brownstone (restricted) of Southwest Arkansas." M. C. Israelsky and A. R. Mornhinveg, Houston, Texas.
19. "Important Zone Fossils of Tertiary and Their Identification." F. B. Plummer, Austin, Texas.
20. "Genus *Buccitriton* as Subsurface Guide Fossil." H. B. Stenzel, College Station, Texas.
21. "Lower Marine Miocene at Stratton Ridge, Brazoria County, Texas." H. C. Vanderpool, Norman, Oklahoma.
22. "The *Venericardia planicosta* Group in the Upper Eocene of the Gulf." Julia Gardner and Edgar Bowles, Washington, D. C.
23. "Foraminifera from Type Locality of Bowden Marl, Jamaica." Frances Charlton, Berkeley, California.
24. "Stratigraphy and Foraminifera of Reef Ridge Shale, California." William F. Barbat and Floyd L. Johnson, Taft, California.
25. "Some Suggestions for Heavy Mineral Investigations." Wm. M. Cogen.

REPORT OF THE SECRETARY-TREASURER*

March 15, 1933

The membership of the Society of Economic Paleontologists and Mineralogists on March 15, 1933, numbered 220 active members and 63 associate members. Dues were collected on January 1, 1933 for 1933. During the year, March 15, 1932 to March 15, 1933, the Society elected 9 new active members and 10 new associate members. Applications now pending number 19.

The Secretary has directed his energies toward maintaining and increasing the revenues of the Society through the sale of back numbers of the Journal of Paleontology, obtaining new subscriptions, new members, and advertising for the Journal of Paleontology. The total paid subscription list of Volume VI of the Journal of Paleontology amounts to 518. The total paid circulation of the Journal of Sedimentary Petrology, Volume II, amounts to 268. At intervals circular letters illustrating and describing the publications of the Society have been sent out to libraries and laboratories, and to geologists and paleontologists in this country and abroad. A number of letters have also been written to prospective advertisers soliciting business. The total advertising amounts to approximately five pages yielding $340.00 revenue. One page, advertising the publications of the American Association of Petroleum Geologists, is in exchange for an advertisement of publications of the Society in the Bulletin, and the one-sixth page advertisement of Max Weg is an exchange for a similar amount of space in *Der Geologie*.

On the Pacific Coast and in the larger cities in Oklahoma, Louisiana, and Texas, local sections have continued active and interesting monthly meetings have been held. It is hoped that these activities will continue and that additional local sections will be organized.

Both volumes of the 1932 issues of the Journals were printed by the George Banta Publishing Company at Menasha, Wisconsin.

Altogether, Volume VI of the Journal of Paleontology contains 352 pages, 52 plates in lots of 1000 at a total cost of $2,632.32. Volume II of the Journal of Sedimentary Petrology contains 166 plates, and was printed in lots of 600 at a cost of $946.17.

* This report was written by Helen Dees, Secretary to Gayle Scott, during Mr. Scott's absence due to sickness.

The present financial status of the Society is satisfactory as shown by the following statement:

CASH AUDIT

SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS
March 15, 1932 to March 15, 1933

This is to certify that I have audited the records of the secretary-treasurer of the Society of Economic Paleontologists and Mineralogists for the period March 15, 1932 to March 15, 1933, and the following represents, in my opinion, a correct statement of receipts and disbursements for that period.

March 20, 1933

JOHN W. BALLARD
Certified Public Accountant

STATEMENT OF SAVINGS ACCOUNT
of the
Society of Economic Paleontologists and Mineralogists
for the year March 15, 1932 to March 15, 1933

Balance March 15, 1932	$1,531.18
Deposit February 21, 1933	1,500.00
Interest July 1, 1932	20.46
Interest January 1, 1933	15.76
	$3,067.40
Withdrawal November 9, 1932	500.00
Balance, March 15, 1933	$2,567.40

The above amount in Savings Account 27574 of the Fort Worth National Bank, Fort Worth, Texas.

STATEMENT OF CASH RECEIPTS AND DISBURSEMENTS
Society of Economic Paleontologists for the year
March 15, 1932 to March 15, 1933

RECEIPTS

Balance March 15, 1932	$2,708.85
Donations toward publication, A. A. P. G.	368.00
Checking account from savings account	500.00
Savings account from checking account	1,500.00
Membership dues	1,059.20
Subscriptions	2,817.83
Advertising	378.12
Plates	2.30
Interest on Savings Account	36.22
Miscellaneous and redeposited checks	94.52
Total Receipts	$9,465.04

Balance March 15, 1932 as follows:

Savings account	$1,531.18
Checking account	1,177.67
	$2,708.85

DISBURSEMENTS

Secretarial and Clerical work	$ 407.50
Postage, Express and Freight	182.61
Telephone and Telegraph	5.03
Reprints authors sheets	7.39
Editorial expense	93.20
Office expense	75.44
Savings account to checking account	500.00
Checking account to savings account	1,500.00
Returned checks	60.00
Printing	
March Journal of Paleontology	543.85
June Journal of Paleontology	509.41
September Journal of Paleontology	402.90
December Journal of Paleontology	536.59
May Journal of Sedimentary Petrology	335.95
August Journal of Sedimentary Petrology	372.31
Plates, Full-tone prints, etc.	870.09
Total Disbursements	$6,402.27
Balance on hand	3,062.77

Reconciliation of Balance:

Savings account balance, March 15, 1933	$2,567.40
Checking account balance, March 15, 1933	505.39
	$3,072.79
Less check outstanding plus tax	10.02
Balance March 15, 1933	$3,062.77

Checking account carried at Forth Worth National Bank of Fort Worth, Texas.
All checks supported by vouchers.
Records kept in a very satisfactory manner.

ASSETS

Bank Balance		
Savings account	$2,567.40	
Checking account (net)	495.37	
		$3,062.77

Stock of Journals		
Journal of Paleontology		
Volume II (59 copies)	354.00	
Volume III (87 copies)	522.00	
Volume IV (318 copies)	1,908.00	
Volume V (367 copies)	2,202.00	
Volume VI (444 copies)	2,664.00	
		7,650.00
Journal of Sedimentary Petrology		
Volume I (300 copies)	900.00	
Volume II (383 copies)	1,149.00	
		2,049.00
Credits from George Banta Publishing Company		4.42
Bills Collectible		
Membership dues	650.00	
Sales of Journals	672.00	
(50) Journal of Sedimentary Petrology Subscriptions	150.00	
(56) Journal of Sedimentary Petrology Membership dues	112.00	
Advertising	205.00	
Due for back issues of Journals	233.70	
		2,022.70
Total Assets		$14,788.89

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Geology of California (1933). By Ralph D. Reed. Approx. 350 pp. 29 halftones, 33 line drawings, 26 tables. 9 x 6 inches. Cloth. $5.00.

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Structure of Typical American Oil Fields. Symposium on relation of oil accumulation to structure. By many authors.

Vols. I-II (1929). Descriptions of typical fields. 1290 pp., 425 illus. 9 x 6 inches. Cloth. To members and associates, $10.00; to non-members, $14.00. Either volume at half these prices.

Vol. III (in preparation). General papers on origin, migration, and accumulation. 900± pp., 40± figs. 9 x 6 inches. Cloth. $5.00.

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